VITAL STATISTICS

AN INTRODUCTION TO THE SCIENCE OF DEMOGRAPHY

BY

GEORGE CHANDLER WHIPPLE

Late Gordon McKay Professor of Sanitary Engineering in Harvard University

NEW YORK

JOHN WILEY & SONS, INC.

LONDON: CHAPMAN & HALL, LIMITED

Stanhope Press
F. H. GILSON COMPANY
BOSTON, U.S.A.

DEDICATED TO

THE STUDENTS OF VITAL STATISTICS
IN THE SCHOOL OF PUBLIC HEALTH
OF HARVARD UNIVERSITY
AND THE
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

1913–1922

PREFACE TO SECOND EDITION

Since the first edition of Vital Statistics was published a new census of the United States has been taken. New data are therefore available. The tables of population have been revised to include the data for 1920 and new tables have been added. Interest in the subject of the estimation of future population of cities has led to a new chapter on this subject, which includes diagrams showing population growth in different parts of the United States. Emphasis is placed on the use of semi-log plotting paper for predicting future population, — a subject which should prove of special interest to business men, city planners, and municipal engineers, as well as to health officers. The international list of the causes of death has been revised in accordance with changes made by the Congress which met at Paris Oct. 11–14, 1920.

No attempt has been made to amplify the questions and exercises at the end of each chapter. They were originally intended to be merely suggestive. Each instructor will obtain the best results by making up problems for his own classes based on local data. It will be noticed that Massachusetts statistics have been largely used throughout the book. This is because the book was prepared originally for use at Harvard University and the Massachusetts Institute of Technology, and the inclusion of data from other states would have made the book too large. It may not be out of place to call attention once more to the fact that this is an elementary book.

The author takes this occasion to express his gratification that the subject of vital statistics is rapidly accelerating in interest. The fact that the first edition of this book has already been translated into the Japanese language and that Italian and Spanish translations are being made is proof that health officers the world over are more than ever appreciating the importance of the science of demography.

In making the changes in this second edition the author wishes to acknowledge the assistance of his secretary, Miss Mabel A. Spear, and of Mr. Dana E. Kepner, Assistant in Sanitary Engineering, Harvard Engineering School.

THE AUTHOR.

CAMBRIDGE, MASS.
November, 1922

PREFACE

This book is written for students who are preparing themselves to be public health officials and for public health officials who are willing to be students. It makes no claim to be an exhaustive treatise or a compendium of facts; it is merely a guide to the study of vital statistics, an introduction to the great world-wide science of demography — a science yet in the magmatic stage, not yet crystallized. The Great War is bound to develop this science, because hereafter all the nations of the earth must know each other better, and this knowledge, in order to be usable, must be condensed into statistical forms.

Specifically the book tells what statistics are and what they are not; it shows how to express vital facts by figures, how to tabulate them and how to display them by diagrams; it shows how to compute birth-rates and death-rates and how to analyze a death-rate; it shows how to adjust and standardize death-rates and how to make life tables; it emphasizes the need of using vital statistics with truth, with imagination and with power.

For the convenience of school instruction, exercises and questions to incite further study are given in each chapter. Many subjects worthy of special study, however, are not even mentioned, loose ends have been left in every chapter, illustrations have been chosen as they came conveniently to hand, and the general arrangement has been informal as to its subject matter. The object in all this has been to stimulate the reader to critically analyze all vital statistics as they appear before him from day to day. Although the illustrations have been gathered in a haphazard way, an attempt has been made to set forth the elementary principles of the statistical method in a simple and orderly fashion.

The author wishes to confess that he is not an authority on vital statistics, much less an authority on demography; he is merely a student of the science. He has taken the student's privilege of quoting freely from many writers to whom he wishes to render acknowledgments and thanks. In particular he desires to express his obligations and personal regards to Dr. William H. Davis, Chief Statistician for Vital Statistics, United States Bureau of the Census, who has read the entire proof of this book and given the benefit of his careful criticism.

Just a personal word to the health officers of America. A new day is dawning for you. The care of the public health is becoming a distinct profession. The medical profession alone is not able to cope with it. The young men and women who are to be the executive health officers in the next generation are recognizing the need of special training, based on the principles of preventive medicine, hygiene and sanitation. Schools of public health are coming into existence and receiving warm-hearted support. The health administration of the future will be in the hands of full-time officials, who are adequately paid and protected in their tenure of office, but who in return for these advantages must be adequately trained for their work. The ability to use vital statistics in public health work is an important part of this training. Many of you have been in office for a long time, you have forgotten most of your arithmetic — not to mention algebra. You can see the new era coming and you dread the new methods founded on accurate statistical studies of accident, disease and death. There is no need of this fear. You can use statistics as well as any one, but you must study. This book has been prepared with your difficulties in mind.

GEORGE CHANDLER WHIPPLE

CAMBRIDGE, MASS.
January, 1919.

CONTENTS

CHAPTER I

DEMOGRAPHY

CHAPTER II

STATISTICAL ARITHMETIC

CHAPTER III

STATISTICAL GRAPHICS

VITAL STATISTICS

CHAPTER I

DEMOGRAPHY

Broadly speaking demography is the statistical study of human life. It deals primarily with such vital facts as birth, physical growth, marriage, sickness and death and incidentally with political, social, educational, religious, sanitary, hygienic and medical matters. In a somewhat narrower sense demography is used as a synonym for vital statistics.

The word "demography" is derived from the Greek words *demos*, people, and *grapho*, to write. It is in common use in Europe, but is not as well known or its meaning as well understood in America. High authority for its use is found in the name of that most important triennial gathering of physicians and sanitarians, the International Congress of Hygiene and Demography.

Demography cannot be called a science in the sense that it is a classified body of knowledge from which laws have been developed and established. But all sciences in their evolution go through a descriptive stage in which data are collected and hypotheses tested. So regarded demography may be called a science, — the science of human generation, growth, decay and death as studied by statistical methods.

The principal divisions of demography. — Demography may be said to include the following major subjects:

1. Genealogy, which considers individual ancestries and personal records.
2. Human eugenics, which considers heredity from a scientific standpoint, and is to a large extent the application of the statistical method to genealogy.
3. The census, that is, the collection of social, political, religious and educational facts concerning population, usually by the method of governmental enumeration.
4. Registration of vital facts, such as those concerning birth, marriage, divorce, sickness and death, usually under governmental direction and by the use of individual records.
5. Vital statistics, which is the application of the statistical method to the study of these vital facts. These might be called bio-statistics.
6. Biometrics, which includes anthropometric studies of human growth, stature, strength, etc.
7. Pathometrics, that is, statistical pathology, which includes detailed studies of diseases and their relations to the human body. These facts are obtained largely in hospitals, by health department laboratories and by life insurance companies.

Demography both old and new. — The word "demography" has come into use during the last generation, and has not even now taken its proper place in the list of recognized sciences; but the gathering together of facts relating to human life and the expression of these facts numerically has been practiced from time immemorial.

Some parts of demography are older than others. Genealogy is very old. "Adam lived an hundred and thirty years, and begat a son in his own likeness, after his image; and called his name Seth: And Seth lived an hundred and five years and begat Enos: And Enos lived ninety years and begat Cainau; And Cainau lived seventy years and begat Mahalaleel:" And so it goes on. Hundreds of years before Christ enumerations of the people were made for purposes of taxation and for other reasons, as one may read in the histories of Egypt, Persia, Judaea, or China. Greece and Rome likewise had their enumerations.

Many fragmentary data relating to births, deaths and marriages were recorded in the old church registers of England. Capt. John Graunt compiled the vital statistics for the city of London in 1662 in a report which attracted much attention at the time. In referring to the Great Plague in London in 1666 Pepys' Diary tells about the published "bills," that is, the list of the dead, and gives their statistics.

But the application of statistics and the scientific method to genealogy is relatively modern and so are the developments of biometry and pathometry. Sir Francis Galton and Professor Karl Pearson, of England, have been leaders in this and may almost be said to have founded a new school of statisticians.

Demography, therefore, is both an old and a new science.

History of statistics. — The word "statistics" is nearly two centuries old, being first used by Gottfried Achenwall, who lived in Jena, 1719–1772. Before that we learn of the political arithmeticians in France and Italy and of Aristotle who used statistics in describing and comparing different states. The systematic publication of the details of official statistics owes its origin to Anton Büschvig, 1724–1793, who published a voluminous work on historiography and founded a magazine in which statistics for various countries were brought together and compared. Crome in 1785 published important *Tabellen-Statistik* which contained various data in regard to population in Germany.

Many well-known scientists undertook statistical investigations. Edmund Halley, 1656–1742, the astronomer who discovered the comet which bears his name, compiled in 1693 a series of mortality tables and calculated the expectation of life at each age and thus laid the foundation for scientific life insurance. In 1713 Bernouilli, noted for his hydraulic studies, demonstrated a theory of probabilities which, a century later, 1813, was perfected by Laplace in his masterly treatise "Theorie analytique des probabilités."

John Graunt, already mentioned, laid the foundations for vital statistics when in 1662 he wrote his remarkable "Natural and Political Observations upon the Bills of Mortality."

In 1741 Joh. Peter Süssmilch (1707–1767) published an important work on vital statistics from which he attempted to draw some far-reaching moral deductions. He tried to demonstrate statistically the doctrine of the "Natural Order." From the equality of the sexes at marriage (at birth his ratio is 21 sons to 20 daughters) he derives the command of monogamy. From a comparison of urban and rural death-rates (in cities one death to 25 to 32 persons, and in the country, one to every 40 to 45 persons) he censures the unnaturalness, immorality, and luxury of city life, "proving statistically" that these bring down the wrath of God.

With the accumulation of statistical data various divergencies began to appear. The political economists, headed by Adam Smith ("Wealth of Nations," 1776) and followed by Malthus (1804) and others, separated themselves from the realm of general statistics. Ritter (1779–1859) led the study of geography apart. At the end of the 18th century the life insurance companies also drew away from the considerations of general populations, and, by reason of the accumulation of their own data relating to deaths, began to depend upon them alone. This splitting up of the general science of statistics and the multiplication of the practical applications of statistics led to an increasing laxity in method, a condition which we have hardly yet outgrown.

Quételet, 1796–1874, aroused much enthusiasm over statistics as "the queen of all the sciences." His work on probability was justly famous and was an inspiration to Florence Nightingale. Since his time, however, this branch of the subject has been more commonly considered as a part of pure mathematics and is treated in books on "Least Squares," the law of error, and precision of measurements.

Finally, we come to the brilliant works of Galton, Karl Pearson and others, already mentioned.

The history of statistics is a fascinating one, as it flits around from country to country, now flourishing in Italy, then in France, England, Denmark, Germany, England again. The United States has had many able statisticians but few statistical mathematicians worthy to be compared to Laplace, Quételet or Karl Pearson.

The world's great demographers. — Some of the greatest scientists of the world have been enthusiastic statisticians. In some cases their greatness has been due to their statistical skill. Even at the present time it is safe to say that the most successful health officers are good statisticians, although it does not follow that all good statisticians are successful health officers.

The following is a short list of men, not now living, who have made important contributions to the study of statistics, — especially vital statistics. The student will find it interesting to add to this list.

Capt. John Graunt (1620–1674), of England.
Melchiorre Gioja (1767–1829), of Italy.
Sir Francis Galton (1822–1911), of England.
William Farr (1807–1883), of England.
Louis A. Bertillon (1821–1883), of France.
Alphonse Bertillon (1853–1914), of France.
Edwin Chadwick (1800–1890), of England.
Florence Nightingale (1820–1910), of England.
Edward Jarvis (1803–1884), of Boston, Mass.
Lemuel Shattuck (1793–1859), of Boston.
Samuel Warren Abbott (1827–1894), of Boston.
Carroll D. Wright (1840–1909), of Massachusetts.

Section of Vital Statistics. — The American Public Health Association has always manifested a keen interest in vital statistics. Some of the reports of its committees have had far-reaching effects. In 1907 a Section of Vital Statistics was organized in this association, and since that date the journal of the association, now known as the American Journal of Public Health, has contained many important articles on the subject. Membership in this section is open to registration officials, statisticians, epidemiologists, sanitarians and other members of the American Public Health Association who are interested in vital statistics.

The "Statistical Method." — Statistics are facts expressed by figures. Strictly speaking a birth reported and recorded officially is not a statistic, but a vital fact; yet inasmuch as reported and recorded births are commonly counted and the results expressed numerically it is appropriate to regard such a birth record as a statistical unit or item, that is, as a statistic. It is not customary, however, to use the word in the singular number.

By expressing facts by figures it is possible to arrange them in various ways for study and comparison, as, for example, in tables and graphs; to classify them; to make generalizations; to use them in logical processes and thus to draw inferences and conclusions based on the facts. The various mathematical processes used for this purpose are collectively known as the statistical method.

Some of these processes are quite elaborate and involve complicated mathematical methods and conceptions, such as the laws of variation, dispersion, correlation and probability. For many years there has been a discussion as to whether "statistics" should be regarded as a distinct science, ranking with physics, chemistry and biology or merely as a method. Westergaard expresses the truest conception when he says that "it is an auxiliary science in many branches of human thought." "There are some statisticians who are statisticians and there are some statisticians who are mathematicians." There are theories of statistics which comprise a very considerable part of mathematics. Volumes have been written on the Calculus of Probabilities, on Least Squares, on Variation. On the other hand, many of the statistical processes are extremely simple and do not get beyond the bounds of ordinary arithmetic. The simple processes have a wide general use; the more elaborate processes have their place but are not commonly applicable or necessary.

Why we need to use the statistical method. — People who do not like mathematics often say "Oh! Pshaw! Why do we have to study statistics? Of what good are they?" The answer is that in a big world we have to deal with many facts and the statistical method enables us to abbreviate facts, to concentrate them so that we can more readily study and compare them and find out what they mean. If you want to live in a little world and deal with only a few facts then you do not need statistics. The head of a small factory may remember the wages of each one of his employees. Tom gets ten dollars a week, Fred gets twelve, Sam and Bill each get fifteen and Henry gets sixteen dollars. But the head of a large factory in which there are a hundred hands cannot carry all these facts in mind. The bookkeeper of course has a record of them, very necessary for pay-day. The head of the factory may know, however, that ten of the employees get sixteen dollars a week, fifteen get twelve dollars and seventy-five get ten dollars. The factory superintendent needs these statistics. He lives in a large world. The village gossip knows the dates of all the births, marriages and deaths in town since January first, but she lives in a little world. To compare these facts with similar facts for the next town and the one next to that requires that the facts be expressed in figures. Statistics enable one to enlarge his horizon.

Why are statistics thought to be "dry"? — Statistics have the popular reputation of being dry, uninteresting, or, as Shakespeare would say, — "flat, stale and unprofitable." This is very natural, for all figures look alike. If we are considering one hundred and thirty-seven tons of coal we use the figures 137 and if we are talking about the same number of American Beauty roses we also use the figures 137. If we think only of the figures we see no difference between these statistics. It does not take much imagination to visualize 137 roses, their beauty and their odor; it takes more, perhaps, to visualize 137 tons of coal. And if 37 of the roses are said to be yellow, 60 white and 40 red, we can visualize the whole mass even if we know that they are mixed. The reason why statistics are "dry" is because people do not try to visualize them. If you don't try to visualize the statistics the figures are commonplace and of course uninteresting, while if you do try the mental effort is tiring. Moreover, there is a real difficulty and that is our inability to visualize very large figures. I may be able to visualize a hundred dollars, but I confess not to be able to visualize a million dollars, even though I know that it is one thousand times as much as one thousand dollars. Also visualization is lost, or at any rate confused, when we begin to perform mathematical operations with our statistics.

The way to prevent statistics from being "dry" is to keep in mind that statistics are not merely figures, but are figures which stand for facts.

Is it true that "you can prove anything by statistics"? — We often hear it said "Oh! you can prove anything by statistics." Is this true? Suppose we substitute the meaning of statistics and say "you can prove anything by facts if expressed in figures." Obviously this is not so. Facts are facts whether expressed in figures or not. If the conclusions are wrong the trouble lies not in the statistics but in the way they are used. The drawing of conclusions is the function of logic, a process of reasoning, and fallacious reasoning should not be charged against statistics.

And yet there is something which underlies the popular statement. When figures are used to express facts, and when the logical processes are applied to figures, divorced in the mind from the facts for which they stand, it is easy for fallacies to creep in without being recognized; it is easy to compare things which ought not to be compared, to generalize from inadequate data, and to commit all sorts of illogical errors. Thus the unscrupulous may fool the unwary, and the innocent may fool themselves. Hence to use statistics properly one must be able not only to visualize the facts but to think logically. Students who would be statisticians should therefore study formal logic. Some of the common fallacies in the use of statistics will be considered on later pages. Honesty and conservatism are essential qualities for the makers and users of statistics.

There are numerous works on logic. One of the best is an old one, — " The Principles of Science," by W. Stanley Jevons. It treats not only of logic but of the scientific method in general.

The national value of " Vital Bookkeeping." — It is of the greatest importance to a nation that accurate records be kept of its vital capital, of its gains by birth and immigration and of its losses by death and emigration, for a nation's true wealth lies not in its lands and waters, not in its forests and mines, not in its flocks and herds, not in its dollars, but in its healthy and happy men, women and children. A well man is worth more to a nation than a sick man; a man in the prime of life is of more immediate worth than an old man or a child, a married man is potentially a greater asset than a single man. Hence, in a nation's vital bookkeeping the number of people, their age and sex and conjugal condition, their parentage, their health, the rate of births and deaths, are matters of great moment. Their environment is also important; their concentration in cities and villages and congested areas, their mode of housing, their occupation, their state of intelligence, their economic condition, their knowledge of sanitation, all contribute to the sum total of their usefulness to themselves and to society.

Vital bookkeeping is carried on much as ordinary bookkeeping; there are daily entries of accessions and losses as they occur, corresponding to receipts and payments; there are weekly statements, monthly statements and annual statements; and at longer intervals there is a taking account of stock, that is, a census. One important difference, however, should be noted. Accounts are accurate records of transactions and if properly kept an exact balance will be obtained Vital statistics are not always accurate, the individual data are incomplete and subject to error; the results, therefore, lack the precision of monetary accounts. It is necessary to keep this fact constantly in mind when interpreting the results of statistical studies. An understanding of the principles of the arithmetic of inexact numbers and of the theory of probability is essential.

Vital statistics are useful for many purposes. To the historian they show the nation's growth and mark the flood and ebb of physical life; to the economist they indicate the number and distribution of the producers and consumers of wealth; to the sanitarian they measure the people's health and reflect the hygienic conditions of the environment; to the sociologist they show many things relating to human beings in their relations one with another.

Vital statistics necessary for health officer. — Vital statistics are not to be collected and used as mere records of past events: an even more important use is that of prophesying the future. An engineer in planning a water supply to last for a generation estimates the future population by the previous rate of growth; so also in laying out a system of streets and sewers and transportation service. The whole idea of city planning is fundamentally based on the use of the vital statistics of what has been as a means of estimating what is to be.

The health officer of a city or he whose duty it is to collect and record the vital statistics should study them as soon as received and not wait until some convenient day when other work is slack and then merely tabulate and make averages for formal reports and permanent records. Vital statistics, especially those of morbidity, should be studied in the making, and just as the meteorologist reads his instruments daily in order to forecast the weather and give warnings of the coming hurricane, so the efficient health officer will daily study the reports of new cases of disease in order that he may be forewarned of an impending epidemic and take measures to check its ravages.

No lighthouse keeper on a rocky coast is charged with greater responsibility than he who is set to watch the signs of coming pestilence from the conning tower of the health department. Making another comparison, we may say that the health service should be organized for rapid work like a fire department, with its rapid facility for learning that a fire exists and its ever ready apparatus for extinguishing the blaze. If the fire alarm is not rung, the blaze will spread, and if cases of disease are not reported the epidemic will likewise spread. The duty of reporting cases of infectious disease rests upon the practicing physicians, and thereby hangs a sad and discouraging tale.

National vital statistics. — It has now become well recognized that the maintenance of accurate records of vital statistics is a proper governmental function, and no nation, state or city can be considered as having a complete governmental equipment which does not provide for the proper collection and permanent record of such statistics. But, as will be seen, even our longest governmental records are relatively short, and for that reason we should be careful in drawing general conclusions from them.

Sweden. — Of modern nations Sweden has a just claim to the longest unbroken series of vital statistics. In 1741 registration of births, marriages and deaths was begun in all parishes and since 1749 a census has been taken each year. The principal data for this long period (1750–1900), were given in a most valuable paper by Sundbärg at the International Congress of Hygiene and Demography in Berlin in 1907.

France. — In 1790 Lavoisier (1743–1794), after the French Revolution, collected extensive data relating to the population of that country, the amount of land under cultivation, etc., but the first actual enumeration of the inhabitants of Paris was not made until 1817.

The civil code of Napoleon. — One of the most important influences affecting modern vital statistics in Europe is the Code Civil of Napoleon. This law, which was merely the codification of the chaotic legislation existing at his time, requires the declaration of a birth or death to the mayor of the community in which the birth or death occurred. Severe penalties are provided for failure to make such declaration within the specified period. Declaration is further assured by the fact that, from a legal standpoint, a person whose birth has not been declared does not exist; he cannot go to school, cannot marry, vote, conduct business, inherit property, or enjoy any civil right. In like manner, deaths are very completely reported. The official record of marriage is greatly facilitated by the fact that the legal marriage is performed at the City Hall by the mayor of the community.

The reason for adopting such a law in France was, doubtless, to keep an accurate record of the men available for military service, but at the same time it has served admirably as the basis of demographic statistics. In viewing the effect of the Code Civil of Napoleon, one must not confine his observations to France alone, but include other European countries, such as Belgium, Holland, Switzerland, Spain, Italy, and Roumania, which have since adopted this Code, more or less modified, as well as those South American countries which have taken the Spanish Code as their model.

England. — In England the old parish records date back at least to 1538, when Henry VIII ordered all parsons, vicars and curates to keep true and exact records of all weddings, christenings and burials. It was not until 1801 that a national census was taken, and it was not until 1851 that a complete census was made. The present system of registration is based on Acts of Parliament between 1836 and 1901.

United States of America. — America is far behind other civilized countries in its records of vital statistics. There is no national registration system, no complete national record of births and deaths. This results from our distributive form of government, the control of such matters being a state function, not a federal one. The records vary greatly in different parts of the country. Some of the older states like Massachusetts and New Jersey possess fairly accurate records that extend back for several decades, but in some of the western and southern states the records are either absent or so incomplete as to be worthless. At the time of the last census, in 1920, the registration area where the death records were considered accurate enough to warrant their being published included 82.2 per cent of the total population of the country. The health statistics of our best administered cities are much inferior to the published vital statistics of European cities, as, for example, those of the Swiss cities or of Hamburg, Germany. The United States Census Bureau, now permanent, has become increasingly efficient in recent years, and its reports are of much value, but not until a centralized public health service has been secured will the nation's vital statistics be put upon a high plane of comprehensiveness and accuracy.

The importance of statistical induction. — In using statistics we necessarily employ the methods of logical thinking comprised in what is termed "induction," methods by which general tendencies and laws are found from accumulations of facts.

Statistical induction may be said to be one of the most potent weapons of modern science. Referring to it Royce said that the technique of statistical induction consists wholly in learning how to take fair samples of the facts in question, and how to observe these facts accurately and adequately.

Statistics are being constantly invoked for testing hypotheses in all branches of science. This involves four distinct processes, — *first*, the choice of a good hypothesis; *second*, the computation of certain consequences, all of which must be true if the hypothesis is true; *third*, the choice of a fair sample of these consequences for a test; *fourth*, the actual test of each of these chosen hypotheses.

Deductive reasoning as well as inductive reasoning is involved in the use of vital statistics. It is perhaps the natural order of mental processes for the mind pursuing an inductive study to leap ahead to some conclusion and then fill in the intervening steps by working backward by deduction.

It is by the application of the principles of logic that the statistician is able to keep his conclusion within reasonable bounds.

Choice of statistical data. — First, there is the *complete statistical study* which includes a full count of all the units within the desired area or within the specified time. This method, of course, brings the surest results, but it is often impossible. Second, is the *monographic method*, a procedure in which a detailed and exact study is made of a particular group. Where the group selected for study is a well-chosen type the application of this method yields valuable results but there is danger in generalizing from monographic researches. The third method is the *representative method*, a study of certain selected parts representative of the whole. This is analogous to the method of the analytical chemist where chosen samples are analyzed and the results applied to the whole. The value of this method depends upon the accuracy of the sampling process quite as much as upon the enumeration of the facts embraced by the sample. The representative method is widely used. There are two general methods of sampling. One is that of *random selection,* the other is that of *mixture and subdivision.* The object in both cases is the same, — to secure a sample truly representative of the whole. The tendency to take samples of the obvious and the accessible is one that must be constantly struggled against.

EXERCISES AND QUESTIONS

1. How can vital statistics be used to determine relative values in public health activities? [See Am. J. P. H., Sept., 1916, p. 916.]

2. Describe the common method used in compiling genealogies. [Consult some systematic genealogy, — say that of your own family.]

3. Prepare a diagram of your own ancestry, giving the names of your father and mother, the dates of their birth (and death) and their birthplaces; also the same information as to your two grandfathers and your two grandmothers; your four great-grandfathers, etc., as far as the information can be readily obtained.

4. Who was Mendel and what is the Mendelian law? [See Rosenau's Preventive Medicine and Hygiene, Chapter on Heredity and Eugenics.]

5. What are the primary laws of heredity and eugenics?

6. What information can you give as to the heights of your father and mother, your grandfathers and grandmothers? Can you illustrate any of the laws of heredity, as to height, color of hair or any other characteristics, from your own family records?

7. Can you suggest a schedule of anthropometric data to be kept for each person as a matter of family record?

8. Write a short biographical sketch of some person famous for work in statistics, demography or vital statistics. (Name to be assigned by the instructor.)

CHAPTER II

STATISTICAL ARITHMETIC

Statistical processes. — The principal processes used in the study of vital statistics are these:

Collection of the facts.
Classification of the facts.
Generalization from the facts.
Comparison of the facts.
Drawing conclusions from the study of the facts.
Display of the facts and the results.

Collection of data. — There are two primary methods of obtaining the data needed in demography — *enumeration* and *registration.* In the first case the statistician goes or sends to get the facts. The persons employed are enumerators or inspectors. This is the method of census taking and is described in another chapter. In the second case the facts are reported to the statistician in accordance with established rules and regulations. For example, physicians and undertakers are required to send notices of deaths and burials to the proper authorities. Some of the methods in common use and the laws which govern the reporting of vital facts are described later on.

It is important to make sure that the data collected are sufficient in kind and number for the purpose for which the statistics are intended. It saves time and labor in the end to consider carefully at the very outset just what data are needed. Where, as is often the case, the statistician has no control over the collection of the data, he should make every possible attempt to ascertain the reliability of the sources of information and not attempt to draw conclusions not warranted by the conditions under which the figures were collected.

Statistical units. — The basic statistical process is counting. An easy process, — one says; and so it is if we know what to count, and if we know what to include and what to leave out. Here at the very outset we meet our first difficulty.

Before going on stop and define a "dwelling-house." Is a church a dwelling-house if the sexton lives in it? Is a garage a dwelling-house if the chauffeur lives in the second story? Is a building with two front doors one dwelling-house or two? Is a "three-decker" one dwelling-house or three? Or try to define an infant, a birth, a cotton-mill operative or any other unit used in demography.

Statistical units are the things counted and represented by numbers. Obviously every fact, every item, counted must be included within the definition of the unit. No part of a statistical study demands more careful study than the definition of the statistical units to be employed. Each unit should not only be rigidly, accurately and intelligibly defined, it should be steadily adhered to during the investigation. This is by no means easy.

In counting the number of deaths in a city should non-residents be included? Should still-births be included in "births"? Has practice in this matter been constant during the last fifty years? Has pneumonia always meant what it means to-day? And what has become of the causes of death which no longer appear on our lists? It is certainly obvious that all statistics relating to the causes of death must be used with the utmost caution, and this is especially the case if the statistics cover a considerable period of time.

Or, let us take the simple matter of age. What is a seven-year old child? Shall we take the nearest birthday, or the last birthday? Or shall we do as is done in some foreign countries and take the next birthday? In the latter case a child at birth is regarded as of age one. Even the United States census has not always followed the same method of ascertaining age.

Errors of collection. — One of the errors of enumeration is failure to find the units to be counted. In taking a census some persons are never found by the enumerators. They may be accidentally missed, or they may be traveling, away from home or hiding. It is said that at the time of the 1911 census in England, where the data are collected on a single day, some of the suffragettes walked the streets for the entire period, so as not to be at home when the enumerators called, arguing that if they could not vote they ought not to be counted. Failure to obtain complete records is still greater when the data are obtained by registration.

The opposite error sometimes occurs, namely over-registration. This is usually due to carelessness; but padded census records have been known to occur.

There are two kinds of errors which need to be distinguished — *balanced* errors and *unbalanced* errors. For example, if a thermometer is correct it may be assumed that a good observer will be as likely to read too high as too low and that in a long series of readings the errors will balance each other. But if the thermometer is at fault all of the readings will be too low or too high, that is, the errors will be unbalanced. Causes of unbalanced errors must be removed if possible or, if not removed, the results must be corrected for them.

In recording such quantities as the height and weight of persons the errors may be regarded as balanced, but physicians in reporting diseases may by their practice of diagnosis introduce unbalanced errors. Again, the aggregation of the records of various physicians may cause these errors to become more or less balanced.

Finally we have the effect of the *personal equation* of the collector. His mind may have certain grooves through which errors creep into his work. If reading a scale he may have a natural tendency to over-estimate the space between divisions, — if counting units he may have a natural tendency to skip some. What is more serious, he may possess the unpardonable statistical sin of carelessness, or worst of all, he may be dishonest. Ignorance and failure to understand the definition of the units that are to be enumerated are also fruitful sources of error.

Tally sheets. — When many items are to be counted, and especially when there are different units which must be kept apart it is convenient to use some form of tally sheet. Each item is first indicated by a line or a dot and these are afterwards counted. There are two common methods — the *cross-five method* and the *cross-ten method.* In the former every fifth item is indicated by a line which crosses four, making a group of five. In the latter nine items are indicated by dots, the tenth by a cross over the dots. Other devices will doubtless suggest themselves to the reader. (Fig. 1).

Tabulation. — For purposes of study and display the collected data are commonly arranged in tabular form, that is in columns and lines. The preparation of tables is an important part of statistical work and cannot be done too well. The object of a table is to bring statistics together for comparison, to condense information. Essential qualities of good tabular work are clearness, compactness and neatness. Tables are expensive to print, hence the most should be made of each one. The following suggestions, if followed, should yield good results:

1. Each table should have a title which tells clearly what the table contains. Preferably the title should be short, but clearness is the main thing. It is excellent training in the use of words to produce an artistic title.

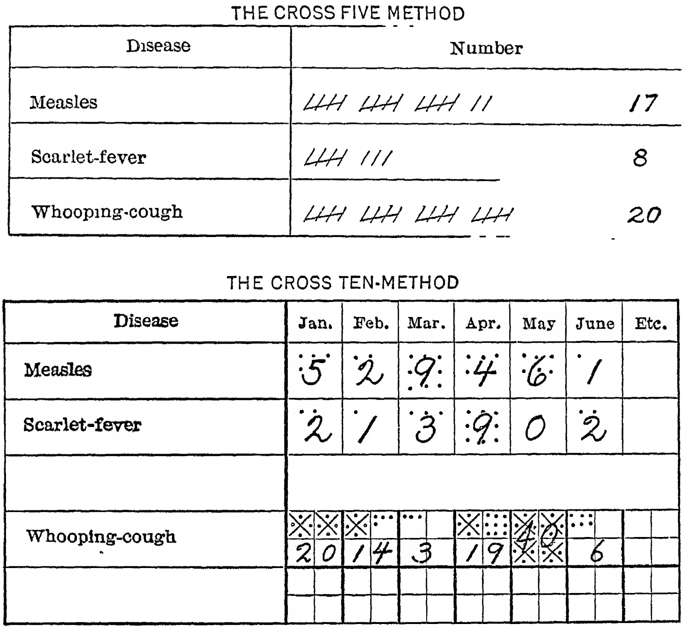


Fig. 1. — Tally Sheets.

2. Each column should have a clear and appropriate heading. As the space for the heading is often small abbreviations may be used, provided they are well understood or well explained in the accompanying text.

3. If the heading is complex, that is, if certain parts of the heading cover more than one column, care should be taken to have this clearly indicated by proper rulings.

Printers call this "boxing." If there are few columns and if the headings are simple, the rulings are unnecessary.

4. If the different columns of a table are likely to be referred to in the text it is convenient to have each column given a serial number from left to right, placed in parenthesis just below the heading.

5. Long unbroken columns of figures are confusing to the eye; especially if the figures of different columns are to be compared on a given line. This trouble can be obviated by leaving horizontal spaces between every few lines or by the use of horizontal rulings. Sometimes, for purposes of reference, each line is given a serial number from top to bottom.

6. The columns of a table should not be widely separated even if there are only a few columns and the page is large. Compactness is a virtue. Much paper is wasted in annual reports by badly arranged tables. On the other hand the type used in tabular work should not be too small.

7. If the figures tabulated have more than three significant figures it is a good plan to separate them into groups of three. Thus, we should not write 6457102, but 6 457 102.

Tables 1 and 2 are given as examples of tabulation and boxing. From this point on students should criticize the tables in this book (a few of which have been intentionally made imperfect), and they should use great care in the preparation of every table involved in the "Exercises and Questions."

TABLE 1

CAMBRIDGE, MASS.

Estimates of Population

Year.	Census	Estimate based on U S. census	Estimate based on U. S and state census	Estimate based on local data.	Estimate used by local board of health.	Estimate used in this report.
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1890						
1						
2						
3						
4						
5						
6						
7						
8						
9						
1900						
1						
2						
3						
4						
5						
6						
7						
8						
9						
1910						
11						
12						
13						
14						
15						
16						
17						
18						

TABLE 2

CAMBRIDGE, MASS.: BIRTH-RATES

Year.	Population estimate	Number of Births.		Birth-rate.		
		Total.	Resident.	Gross.	Resident.	As stated by, etc
(1)	(2)	(3)	(4)	(5)	(6)	(7)

Inexact numbers. — In vital statistics we are usually compelled to deal with data[1] which are not strictly accurate. The figures used to express the results, therefore, should be prepared with this fact in mind. Unnecessary figures should be omitted and only those digits should be included which are supported by the data. Two guiding principles should be followed in making numerical statements of data; — first, to have the figures of the compilation depend upon and indicate the accuracy of the observations; and, second, to carry the final numerical result no further than practical use demands.

Let us take as an illustration the result of the U. S. Census of 1920, according to which the population of the

[1] Do not misuse this word. It is a plural word. The singular number is "datum," but this is seldom used. Do not say, "The data *is* . . . ," but "The data *are*. . . ."

country is stated as 105,710,620. Obviously this figure cannot be strictly true. Let us suppose the possible error to be as much as 200,000. We might write the result "106 million"; but this would be needlessly crude, though accurate enough for some purposes. We might say that the population was between 105.5 and 105.9 million, or we might write 106,000,000 ± 0.2 per cent. The U. S. Census Bureau publishes the figures as collected, leaving it for him who uses the figures to abbreviate them into round numbers according to the use which is to be made of them.

Experience has shown that very few measurements or observations of anything are accurate to five significant figures, many not to three, and some are doubtful in the second figure.

In tabulating the results of original data it is best to give the figures as obtained. But in discussing the results it is better to use round numbers, the number of significant figures depending on the accuracy of the data and the needs of the problem at hand.

In presenting figures orally to an audience it is especially important to use round numbers. Nothing is more deadening than for a speaker to tire the ear with the reiteration of meaningless digits.

Example. — Let us suppose that the number of bacteria on a plate can be counted within five per cent, plus or minus, and that three different tests gave the following numbers: — 2790, 4220 and 3470 per c.c. the average being 3493. Five per cent of this figure is 175; — hence the true result might conceivably lie between 3318 and 3668. Obviously it would be sufficiently accurate and for many reasons better to state the result as 3500 per c.c. Recognizing these unavoidable errors in our present methods the Committee on Standard Methods of Water Analysis of the American

Public Health Association has suggested that statements of analysis should be limited in significant figures as follows: Unfortunately the rule has not been lived up to.

TABLE 3

RULE FOR STATING THE RESULTS OF BACTERIAL COUNTS IN WATER ANALYSIS

Numbers of bacteria found	Records to be made.
1 to 50	As found
51 to 100	To the nearest 5
101 to 250	" " " 10
251 to 500	" " " 25
501 to 1,000	" " " 50
1,001 to 10,000	" " " 100
10,001 to 50,000	" " " 500
50,001 to 100,000	" " " 1,000
100,001 to 500,000	" " " 10,000
500,001 to 1,000,000	" " " 50,000
1,000,001 to 10,000,000	" " " 100,000

Perhaps, sometime, demographers will prepare a similar table for the use of round numbers in vital statistics.

Vital statisticians should at least endeavor to follow the example of the bacteriologists and by concerted action cut out fictitious accuracy from their reports.

Precision and accuracy. — Numerical statements of measurements are accurate as they approach the true value of the thing measured; they are precise as they approach the mean of the measurements. Accuracy takes into account unbalanced as well as balanced errors; precision is concerned with balanced errors only. It is possible for results to be precise and yet be erroneous.

Combinations of inexact numbers. — When data which differ in precision are combined it is possible that faults may be obscured. Let us take the case of a simple addition of the three items in column (1).

TABLE 4

EXAMPLE OF COMBINATION OF INEXACT NUMBERS

Item.	Percentage error.	Possible error in item.
(1)	(2)	(3)
47,386	2	± 948
9,453	5	± 473
843,782	0.5	±4219
Sum 900,621		±5640, or 0.6%

The true value of the sum may lie between 895,000 and 906,000. The result may be written, therefore, 900,000 ± 0.6 per cent. The percentage error of the sum would not, of course, be the sum or even the average of the figures in the second column.

Ratios. — The ratio between two numbers may be expressed as a common fraction or may be indicated by the ratio symbol, the colon (:). Thus we may write $\frac{4}{8}$ or 4 : 8. If the figures are small the difference between the two numbers can be visualized, but if they are large, as for example $\frac{165}{217}$, or 165 : 217, it is difficult to appreciate their meaning. If common fractions are used to indicate ratios they should be limited to those in which the denominator is below 10, or is some round number, such as a multiple of 5 or 10. Thus we might speak understandingly of a $\frac{1}{4}$ or a $\frac{1}{6}$ or a $\frac{1}{25}$ or a $\frac{1}{200}$, but not of a $\frac{1}{17}$ or a $\frac{1}{283}$.

For most purposes in statistical work decimal fractions are to be preferred to common fractions. They facilitate printing as they occupy only one line and do not require the use of smaller type. It must never be forgotten, however, that a decimal fraction is composed of two parts, just as a common fraction, namely the figures which are printed and unity (or one) which is not printed. Thus $\frac{3}{4} = \frac{0.75}{1} = \frac{75}{100}$ $= 0.75$. A decimal fraction is therefore just as much a ratio as a common fraction.

In statistical work we are constantly obliged to compare facts on the basis of their ratios. Let us suppose that we desire to compare cases and deaths from typhoid fever in three different places and that the data are as follows:

TABLE 5

Place.	Cases.	Deaths.
(1)	(2)	(3)
X	541	46
Y	672	53
Z	247	30

In order to make the comparison we must select either one or the other quantity as a base, either cases or deaths. If we select one death as the unit base we have the following ratios:

TABLE 6

Place.	Number of cases to one death.
(1)	(2)
X	11.8 *i.e.* 541 ÷ 46
Y	12.7 672 ÷ 53
Z	8.2 247 ÷ 30

If we select one case as the unit base we have the following ratios, expressed as decimals:

TABLE 7

Place.	Number of deaths to one case
(1)	(2)
X	0.085 *i e.* 46 – 541
Y	0 079 53 ÷ 672
Z	0 121 30 ÷ 247

We might however select 100 cases as the base unit, in which case the figures are 100 times as large and we have

TABLE 8

Place.	Per cent of cases which resulted in death
(1)	(2)
X	8 5
Y	7 9
Z	12 1

Rates. — Now rates are merely ratios referred to some round number as a base. When 100 is used as the base we have a percentage rate, that is a rate per one hundred; but we may use 10 or 10,000 or even 100,000 or 1,000,000 as the base, and very often do so. In many cases we use *one* as the base. Thus we speak of "gallons of water per day," meaning the number of gallons of water for *one* day, the "number of persons per square mile," meaning, of course, one square mile. All of these rates, where only two quantities are compared may be called simple rates. Simple rates have only one base.

Compound rates are those which have two bases. Thus we speak of "gallons of water per capita per day," meaning the number of gallons of water used by one person in one day. The "number of births per 1000 marriages per annum" would also be a compound rate. Most of the rates used for comparison in vital statistics are compound rates as they involve both number and time, the latter often being understood as one year, the calendar year perhaps.

Misuse of rates. — Fictitious accuracy in the use of rates and ratios should be avoided. If 35 out of 57 balls were white the percentage of white balls would be 61.404 per cent. The smallest possible error, *i.e.*, 1, would change the percentage to 59.65 per cent or 63.16 per cent. To use two or even one place of decimals is here absurd. Clearly for figures less than 100 fractions of per cents are illogical. In the same way death-rates for populations of less than 1000 are useless beyond the third significant figure. Comparisons of averages of fictitious values are also to be avoided.

Changes of base in the computation of rates should be kept in mind in order to avoid error of statement. Here is a well-known illustration: In the year 1880 the receipts of a water company were $400,000; between 1880 and 1890 they increased 10 per cent, that is, they became $440,000; between 1890 and 1900 they decreased 10 per cent, that is, they became $396,000 (not $400,000). It is said that a strike once resulted from this fallacy. A company found it necessary to reduce wages 20 per cent for a certain period, promising to raise the wages 20 per cent at the end of the period. Naturally the men who were reduced from $2.00 a day to $1.60 thought they would have their pay restored to $2.00 but found that the company wished to give only $1.60 + 20 per cent or $1.92. The base used should be stated in words if it is not perfectly clear from the context.

When interpreting ratios it should be carefully noted whether or not the numerator bears a direct relation to the denominator. In proportion as it fails to do so any inference from it is less valuable. The ratio between the number of births and the total population is less close than that between the number of births and the number of married women of child-bearing age.

Ratios are sometimes necessarily used in an indirect way. Thus the average annual exports and imports are taken to represent the business condition of a country. Here, a part is taken for the whole. The method is proper if, in the interpretation, it is recognized that it is a part. Or the typhoid fever death-rate of a city is taken as an index of the sanitary quality of the public water supply. It may indeed be such an index, but it is not the only one.

In the same way crude death-rates based on total population regardless of sex or age are less useful in studying relative hygienic conditions than when these factors are taken into account.

Index. — When it is not possible to find a simple direct ratio between two quantities, it is sometimes possible to combine several ratios which taken together give a better indication of the conditions than any one ratio used alone. Thus the prices of various standard commodities sold in any one year may be combined to give a single figure which will indicate the state of trade during that year. This combined result compared with a similar result for the following year will enable one to compare the state of trade in the two years. When several quantities are thus combined the result is called an Index, or an Average Index. Obviously there are various ways in which a combination may be made. Sometimes the weighted average of several quantities is used.

The index has not come into use to any extent in the study of vital statistics, but it would seem logical to use it in comparing the relative hygienic conditions of different cities. This is partially accomplished when crude death-rates are "corrected" or adjusted to take into account the composition of population as to age, sex and nationality.

Some attempts to compute a satisfactory sanitary index will be referred to later on.

Computation of rates. — The computation of a death-rate for a city is merely a problem in long division. As most health officials and some college students will have forgotten their arithmetic by the time they read this book a few words as to computation may be pardoned. The computation sheet should show a record of what has been done and should bear the date and the name or initials of the computer.

Let us suppose that in a city of 34,691 people, as shown by the census of 1910, the number of deaths in that year was 549; what was the death-rate per thousand of population? In the first place how many thousands of population were there? Answer, by pointing off three places, 34.691. All that is necessary then is to divide 549 by 34.691. This may be done in several ways

The operation of long division may be done in full, thus:

```
34.691)549.000(15.82 = death-rate per 1000.
       34691
       -----
       202090
       173455
       ------
        286350
        277528
        ------
          88220
          69382
          -----
```

If we are content to be a little less accurate we may shorten the work by leaving off one decimal of the population, thus:

```
34.69)549.00(15.82 = Answer
      3469
      20210
      17345
       28650
       27752
         8980
         6938
```

The result is not changed. If we write 34.7 instead of 34.69 we shall get

```
34.7)549.0(15.82 = Answer
     347
     2020
     1735
      2850
      2776
        740
        694
```

Still no change. Suppose we try 35 as a round number for the population instead of 34.7 or 34.69 or 34.691. We then get

```
35)549(15.7 = Answer
   35
   199
   175
    240
    245
```

This is evidently incorrect in the decimal. We have gone too far in using a round number for the population.

By using discretion in omitting decimals from the population divisor much work may be saved. It is pitiful to see the energy and time wasted by some health officers in using unnecessary decimals in performing long-division operations, especially as there are so many labor-saving devices available. An easier way is to use a table of logarithms, and a still easier way is to use a slide-rule, a mechanical device for applying logarithms where approximate results will suffice.

The desirable degree of accuracy of death-rates is discussed on a later page.

Logarithms. — Of course you have forgotten how to use logarithms. Let me remind you.

If you multiply 10 by 10 you get 100. You have put two tens together, and you might write them thus 10^2 and say that $10^2 = 100$. If you put three tens together you get 1000. So that $10^3 = 1000$. And so on. Now, ten is the base of logarithms, and we say that the log (meaning logarithm) of 100 is 2, because 2 tens multiplied together makes 100. And the log of 1000 is 3 and the log of 1,000,000 is 6. So also the log of 10 is 1, the log of 1 is 0, and the log of 0.1 is minus 1, *i.e.*, -1, and so on down. Now if the log of 10 is 1 and the log of 100 is 2, what is the log of 20? It is between 1 and 2; it is 1 plus something. Just what this something is you can find from a table of logarithms. A short table (five places) gives for the log of 2 the figures .30103, so that the log of 20 is 1 plus .30103, or 1.30103. In the same way the log of 200 is between 2 and 3; in fact it is 2.30103. And so we can find the logarithm of any number, taking the decimal from the printed table, and putting down the figure to the left of the decimal point according to the size of the original figure, remembering that for figures

Above	1	but below	10,	the log is	0.............
	10	"	100,	"	1.............
	100	"	1,000,	"	2.............
	1000	"	10,000,	"	3.............

The whole number of the logarithm, known as the "characteristic," is always one less than the number of digits in the number under consideration.

We use those logarithms in this way. Suppose we wish to multiply 100 × 10,000. We might do this in the regular way,

$$\begin{array}{r} 10{,}000 \\ 100 \\ \hline 1{,}000{,}000 \end{array} = \text{Answer.}$$

But the log of 100 is 2 and the log of 10,000 is 4. If we add these logarithms we get 6, and 6 is the log of our answer. That is by adding the logs of two numbers, the sum will be the log of the product of the numbers.

And also if we subtract the log of one number from the log of another the difference will be the log of the quotient obtained by dividing the second number by the first. Thus in our death-rate problem the log of 549 is 2.73957 and the log of 34.691 is 1.54022. Hence,

$$\begin{array}{l} 2.73957 \\ 1.54022 \\ \hline 1.19935, \end{array} \text{ which is the log of } 15.82 = \text{the answer.}$$

It must be remembered that the logarithm table contains only the decimals. That is we look up the number which corresponds to the decimal .19935 and find the figures to be 1582. The whole number of the log, being 1, tells us that the result is between 10 and 100, and therefore must be 15.82.

In this way the use of logarithms may save the statistician much time.

A table of logarithms of numbers from 1 to 1000, carried to five decimal places, may be found in the Appendix. Tables in which there are six or seven places of decimals can be purchased and are in common use.

Those who do not feel confidence in themselves in using logarithms should consult a textbook of algebra.

The slide-rule. — The slide-rule is a mechanical device for adding and subtracting the logarithms of numbers, and therefore it enables one to multiply the numbers for which the logarithms stand. It does not add or subtract the numbers themselves.

In using the slide-rule it is first necessary to understand the scale. The logarithms of the numbers from 1 to 10 are as follows:

TABLE 9

LOGARITHMS OF NUMBERS: 1 TO 10

Number	Logarithm.	Number.	Logarithm.
(1)	(2)	(3)	(4)
1	0 00000	6	0 77815
2	0 30103	7	0 84510
3	0 47712	8	0 90309
4	0 60206	9	0 95424
5	0 69897	10	1 00000

and above 10 the decimals repeat themselves, thus

20	1.30103
30	1.47712

etc.

If these are plotted on a uniform scale we get the result shown in Fig. 2A. It will be noticed that on the number scale the divisions grow smaller as the numbers increase. It is this number scale which appears on the slide rule. There are many subdivisions. The space from 1 to 2 is divided into 10 parts, and so are the other spaces. The space between 1 and 1.1 is also divided into ten parts; but above 2 there is not room for so many lines, so the values of the divisions change and one must be on his guard not to make an error in scale reading. It should be remembered that just as the main divisions between 1 and 10 are unequal, so are the subdivisions be-

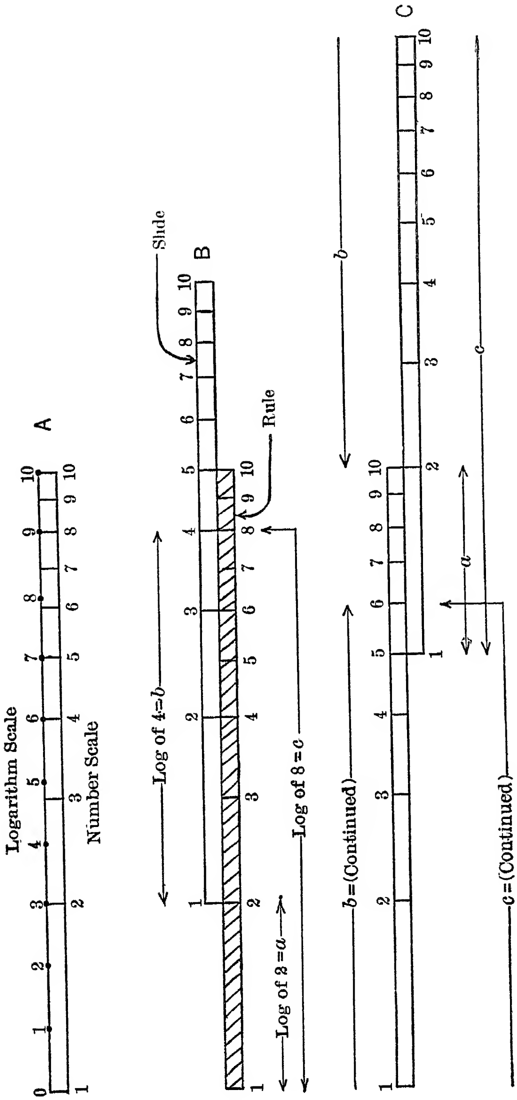


Fig. 2. — Use of the Slide-rule.

tween 1 and 2 unequal. The minor subdivisions are also unequal but the eye cannot distinguish these small differences.

Let us first learn how to multiply two numbers — say multiply 2 by 4. We use the lower scale on the slide and the lower scale on the rule under it. The two scales are just alike. If the left-hand end of the slide is set on 2 of the rule, then the distance (*a*) along the rule is the log of 2, and the distance (*b*) along the slide is the log of 4. The sum of (*a*) and (*b*), *i.e.*, (*c*) is the sum of the logs of 2 and 4 and therefore is the log of their product. And so we find that the distance (*c*) from the end of the rule gives us 8, the result, under the figure 4 of the slide. (See Fig. 2*B*).

Suppose, however, that we want to multiply 2 by 6. The distance (*c*) would then extend to 6 on the slide, or beyond the scale of the rule. That is the product is more than 10. Remembering that the log numbers repeat themselves above 10, all we have to do is to set the right-hand instead of the left-hand end of the slide on the figure 2, of the rule and then read on the rule the number under 6 of the slide. It is seen to lie between 1 and 2. If the subdivisions of the rule were shown on the diagram (Fig. 2*C*) it would be seen that the answer is 12.

The process of division is just the reverse of that of multiplication. To divide 8 by 4, set 4 of the slide over 8 of the rule and read 1 (the end) of the slide on the rule (*i.e.*, 2).

The upper marks on the ordinary slide and rule are not needed for simple multiplication and division. The movable wire is used as a guide and reference mark.

To return to our death-rate problem (above) we may divide 549 by 34.69 by setting 3469 on the slide over 549 of the rule and reading 1 of the slide on the lower scale of the rule. The result is 158+ as before. It is difficult to set 3469 exactly, so it is impossible to read the result to more than three significant figures.

The slide-rule gives only the sequence of figure. It does not give the decimal point. That can best be determined by inspection. (There are indeed rules for the decimal point, but they are hard to remember and one need not attempt to do so.) Inspection shows that 34 goes in 549 more than 10 and less than 20 times; consequently the slide-rule result is 15.8+.

Slide-rules are made in many different lengths, from three or four inches up to twenty inches. A ten-inch rule is best for general use. The twenty-inch rule is easier on the eyes and can be read closer, but it cannot be carried in the pocket. Celluloid rules are the best, as the marks are clear, but cheap wooden rules are satisfactory for some purposes.

Books of instruction accompany most of the high-grade rules and can always be purchased.

Every statistician ought to know how to use logarithms and how to read a slide-rule. Life is too short and time nowadays is too precious to depend upon the old methods of long division and multiplication if much work is to be done.

Classification and generalization. — For purposes of study it is usually necessary to sort out the various data, divide them up into classes, groups or series and to make generalizations in various ways. Some of these processes are very simple; others are rather complicated. The methods used vary according to the nature of the problem at hand. As far as possible the simple methods should be preferred to the more complex procedures.

Classes, groups, series and arrays. — Collections of units which differ from other collections by characteristics which cannot be expressed in figures are properly termed sections or *classes*. Thus, populations are divided into classes according to sex, nationality, conjugal condition, civil divisions.

Collections of units which differ from other collections by characteristics which can be expressed in figures are called *groups*.[1] As an example populations are divided into age

[1] This distinction is not universally made, but if rigidly adhered to it would result in greater clearness of expression.

groups, or into groups of persons having different weights or heights.

Data are also arranged in *series* according to some natural sequence or some order of magnitude or chronological order. When all of the items of a given group are arranged in order of magnitude from small to large, or large to small, they are said to be placed in *array*. Companies of soldiers arranged with the tallest man at one end of a rank and grading down to the smallest man at the other end form an array.

Classes of data. — Little need be said about classification except that the definitions of classes should be clearly and accurately stated, and so drawn as to be mutually exclusive, that is, it should not be possible for an item to appear in more than one class.

Generalization of classes and groups. — The *average*, although a convenient device for generalizing the facts in a class or in a group of observations, has a number of shortcomings. It does not give a true picture of the different items. Two groups may have the same average and yet be composed of very different items. Thus:

	6	1
	6	1
	7	2
	7	3
	9	28
Sum	35	35
Average	7	7

In a large number of items there may be one important item of large magnitude which might be concealed by the average. On the other hand a large item, if erroneous, might unduly raise the average and give a false generalization. Another name for the average is the *mean*.

Some other forms of generalization, therefore, are necessary in statistical work.

The array and its analysis. — If the items are arranged in order of magnitude with the smallest at one end and the largest at the other they are said to be in *array*. If the number of items is not too great this gives an excellent picture of the group. Thus Fig. 3 shows at a glance that the two groups on page 40 are different from each other.

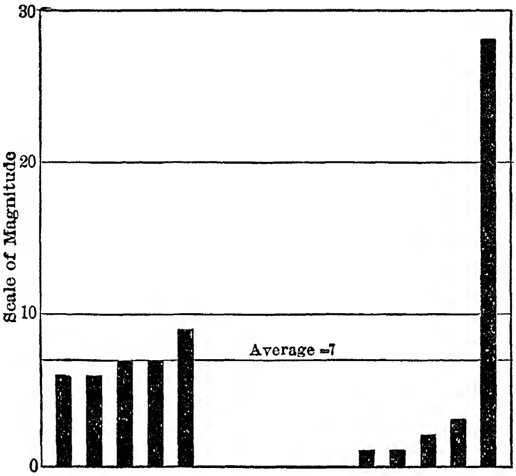


FIG. 3. — Example of Differing Groups which have the Same Average.

In an array the magnitude of the middle item is called the *median*. This is a very important unit in statistical analysis. The means are the same for the above-mentioned groups, *i.e.*, 7, but the medians are different, *i.e.*, 7 and 2. The median may be the same as the mean, — in fact, it usually is near the mean, — but it need not be the same.

The *mode* is the magnitude of the item which is most common among the items. A modish bonnet is one very commonly seen; it is the fashionable one. In one of our two groups there are two sixes and two sevens and we cannot tell which is the mode. They are tied for first place. In the other group the mode is clearly *one.*

The magnitude of the item halfway between the median and the upper limit is called the *upper quartile,* and the corresponding item towards the lower end, the *lower quartile.* A quartile is one-quarter of the way from one end of the array to the other. See Fig. 4.

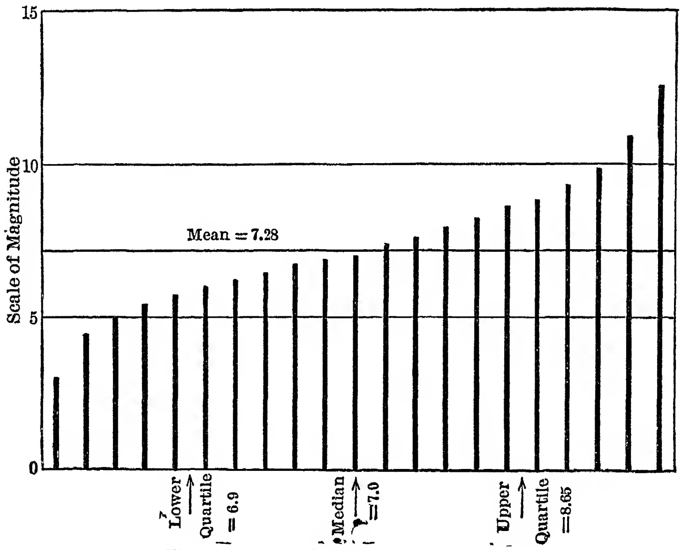


Fig. 4. — An Array of Observations.

If there is an even, instead of an odd, number of items the median may be taken as the average of the two terms in the middle. The same method may be used for getting the quartiles.

The magnitude of the item one-tenth of the way from the lower to the upper limit of the array is the lower *decentile.* And so there may be *quintiles,* and other " iles."

These various units help very much to give one a picture of an array. They are used in various combinations, and ratios are made up by using them.

The average, together with the maximum and minimum, offers a common form of generalization. The median, together with the upper and lower decentiles, is sometimes used. The quartile difference, that is the difference between the two quartiles, is used.

Again the ratio of the maximum (or minimum) to the mean, the ratio of the quartiles to the median, the ratio of the mean to the median, and other ratios have been used.

Still another way is to find the extent to which the different items differ from the mean and study these differences.

This subject, which involves such matters as variation, dispersion and the like, takes us into the very heart of the statistical method and will be treated at length in Chapter XIII.

Groups. — The problem of arranging statistical data into groups is a troublesome one, — troublesome because there are several ways in which groups can be made and defined.

Let us take the case of nine persons whose illness from a certain disease lasted respectively 13, 11, 6, 9, 12, 10, 8, 17 and 13 days. We will consider these merely as whole numbers and try to arrange them in groups. A common way would be:

	(1)	(2)	(3)	(4)
Days.	0–5	5–10	10–15	15–20
Number of persons...	0	4 (or 3?)	(4 or 5?)	1

There is confusion here because one does not know whether to put the item 10 into the second or third group. The groups are not clearly stated. They are not mutually exclusive.

Another way would be to arrange the groups thus, making the upper and lower limits both inclusive.

	(1)	(2)	(3)	(4)	(5)
Days..............	0	1–5	6–10	11–15	16–20
Number............	0	0	4	4	1

A better way would be this:

	(1)	(2)	(3)	(4)
Days	0–4	5–9	10–14	15–19
Number	0	3	5	1

The last two methods are both used. The means for the four groups in the last method would be respectively 2 (average of 0 to 4), 7, 12 and 17. The means for the five groups in the next to the last method would be 0, 3, 8, 13 and 18.

Let us next take a case where we have to deal with whole numbers and fractions, — say to the nearest quarter, — and where the items are 54, $52\frac{1}{4}$, $51\frac{1}{2}$, 57, $50\frac{1}{4}$, $54\frac{3}{4}$, $51\frac{1}{2}$, $56\frac{1}{4}$, 58 inches. We may group them thus:

	(1)	(2)	(3)
Inches	50, $50\frac{1}{4}$, $50\frac{1}{2}$, $50\frac{3}{4}$	51, $51\frac{1}{4}$, $51\frac{1}{2}$, $51\frac{3}{4}$	52, $52\frac{1}{4}$, $52\frac{1}{2}$, $52\frac{3}{4}$
Group limits, inches	50–$50\frac{3}{4}$	51–$51\frac{3}{4}$	52–$52\frac{3}{4}$
Mean of group	$50\frac{3}{8}$	$51\frac{3}{8}$	$52\frac{3}{8}$
	and so on		

With measurements of quarters it is not possible to devise a grouping such that the mean of each group is an even number. Neither $50\frac{3}{4}$–$51\frac{1}{2}$ nor $50\frac{1}{2}$–$51\frac{1}{4}$ would give 51 as the mean.

If, however, we had observations in which the fractions were thirds, or fifths, or with some other odd-numbered denominator, we might do so. Thus if we had $50\frac{2}{3}$–$51\frac{1}{3}$ the mean would be 51; or if we had $50\frac{3}{5}$–$51\frac{2}{5}$ the mean would be 51. Sometimes it is an advantage to arrange the group so that the mean of the group is a whole number, but often this does not matter.

Again let us suppose we are dealing with whole numbers and decimals (to tenths only). Here the denominator is not an odd number. We might arrange the groups thus:

	(1)	(2)	(3)	(4)	
Limits............	0	0.1–1 0	1 1–2.0	2 1–3.0	etc.
Mean of group.....	0	0 55	1.55	2.55	

or

	(1)	(2)	(3)
Limits.......................	0–0.9	1 0–1 9	2.0–2.9
Mean of group................	0.45	1.45	2.45

If the observations were made to the nearest hundredth we might have

	(1)	(2)	(3)	(4)
Limits...........	0	0.01–1.00	1.01–2 00	2.01–3 00 etc.
Mean...........	0	0 505	1 505	2 505

If we had observations of much greater accuracy we would approach the following round numbers as the means of the groups:

	(1)	(2)	(3)	(4)
Limits..	0	0. + ..1.0	1. + ...2.0	2. + ...3.0
Mean...	0	0.5	1.5	2.5

Group designations. — In describing groups it is technically proper to designate the upper and lower limits of the group. For whole numbers this is perfectly simple. Thus in our table we may give

	Age
(1)	0–4
(2)	5–9
(3)	10–14
(4)	15–19 etc.

If the whole numbers are followed by fractions we may assume that any fractions are attached to the whole numbers and that the maximum figure includes the largest possible fraction less than one. Thus $19\frac{1}{2}$ would go in the fourth group, 14.641 would go in the third group. The sign (–) here stands for " to," *i.e.*, 0 to 4.

Sometimes to save space in printing only one group limit is given, the other being understood. Thus in the report of the Registrar General of England we find the following age groups tabulated:

Age	
0–	Meaning 0 to 4 plus fractions
5–	Meaning 5 to 9 plus fractions
10–	etc.
15–	

Where the groups differ by *one*, this method is the only practicable one. Thus

Age
0–
1–
2–
3–

Here we could not state an upper limit without using fractions.

A better nomenclature perhaps would be to use the plus sign instead of the dash, indicating that any fractions were attached to the whole number. Thus:

Age
0+
1+
2+
3+
etc.

Let us compare two groupings, *a* and *b*, the limits of which are stated as follows:

a	*b*
4+	4–4¾
5+	5–5¾
6+	6–6¾

The inference would be that the first group of *a* included items of magnitude 4 and of 4 plus any fraction attached to it however small. The average of the items in this group would be 4.5. In the case of *b*, however, the inference would be that the measurements were made to the nearest $\frac{1}{4}$, and that the items in the first group would be only 4, $4\frac{1}{4}$, $4\frac{1}{2}$ or $4\frac{3}{4}$, the average of which would be $4\frac{3}{8}$.

Percentage grouping. — It often happens that what is wanted is not so much the number of items which fall in each group as the relative number in the different groups. In this case we take the total number of items as 100 per cent and find the per cent which the number of items in each group is of the total, that is, we make a percentage grouping, or a percentage distribution.

In a certain outbreak of typhoid fever the cases were distributed according to age as follows:

TABLE 10

AGE DISTRIBUTION OF TYPHOID FEVER CASES

Age group.	Number of cases in group.	Per cent of cases in group.
(1)	(2)	(3)
0–4	42	8.3
5–9	77	15 3
10–14	82	16.3
15–24	140	27.7
25–34	85	16 8
35–44	45	8.9
45–	34	6 7
Total	505	100 0

The figures in the third column are computed from those in the second. The use of the slide-rule greatly facilitates such computations. The author made the above computation of percentages with the slide-rule in less than two minutes. For comparison he made the same computations by long division, finding that it required three times as long.

Cumulative grouping. — A cumulative or summation group is one which includes the data for previous groups, that is, all of the data from the beginning of the series up to the group limit. An illustration will make this clear.

TABLE 11

AGE DISTRIBUTION OF CASES OF POLIOMYELITIS

Brooklyn, N. Y., 1916

Age group	Per cent of cases in group	Age group (cumulative)	Per cent in group.	Per cent less than stated age.	Age.
(1)	(2)	(3)	(4)	(5)	(6)
0–	8 5	0–	8 5	—	—
1–	22 0	0–1	30 5	8.5	1
2–	23 9	0–2	54 4	30.5	2
3–	19 0	0–3	73 4	54 4	3
4–	7 2	0–4	80 6	73 4	4
5–	6 6	0–5	87 2	80 6	5
6–	3 7	0–6	90 9	87.2	6
7–	2.5	0–7	93 4	90 9	7
8–	1 5	0–8	94 9	93.4	8
9–	1 3	0–9	96 2	94 9	9
10–	0 8	0–10	97.0	96 2	10
11–15	2 0	0–15	99 0	97.0	11
16–	1 0	0–	100 0	99.0	16
	100 0			100.0	

The figures in the fourth column were obtained by successive additions of the figures in the second column. It is more common perhaps to state the results of cumulative grouping in the manner shown in columns five and six. If there are 30.5 per cent in the cumulative group 0–1, it is obvious that 30.5 per cent of the cases were younger than 2 years.

The summation table is very useful in many statistical problems.

Averages. — The simplest, most common, and in general the most useful method of generalizing the results of a set of observations is the *average*, or arithmetic *mean*. The word mean is practically synonymous with the word average, but some writers apply the former to the generalization of a group, using the latter to indicate the arithmetical process.

The average is found by dividing the sum of the magnitudes of a number of items by the number of items. The average of 13, 19 and 25 is $\frac{13 + 19 + 25}{3} = \frac{57}{3} = 19$. The average of 12, 14, 10, 5 and 9 is $\frac{12 + 14 + 10 + 5 + 9}{5} = \frac{50}{5} = 10$.

Now what is the average of all the items in both of these groups? Without thinking we might say that it is $\frac{19 + 10}{2} = 14.\frac{1}{2}$, but this would be wrong. To prove it add together the items and we have

$$\frac{13 + 19 + 25 + 12 + 14 + 10 + 5 + 9}{8} = \frac{107}{8} = 13\tfrac{3}{8},$$

which is the true answer. The reason why we cannot take the average of the two averages is because the second group has five items and the first group only three. The second group being larger ought to be given a greater weight in combining the two.

Suppose that we give the second group greater weight than the first in proportion to the relative numbers of items in the two groups. We then have

19 (the average of the first group)	$\times$ 3 =	57
10 (the average of the second group)	$\times$ 5 =	50
The sum is		107

and $107 \div 8 = 13\frac{3}{8}$.

This is what is called a "*weighted average.*" It is often very useful. Let us take another example of this.

If one man in a factory earned \$30 per week, three earned \$20 and one hundred earned \$10, what is the average wage per man? Certainly not $\frac{30 + 20 + 10}{3}$. It is

$$\begin{array}{rrl} \$30 \times & 1 = & \$\ \ 30 \\ \$20 \times & 3 = & \ \ 60 \\ \$10 \times & \underline{100} = & \ \ \underline{1000} \\ & 104 & \$)\overline{1090} \\ & & \$10.48 \end{array}$$

In reality this is merely an abridgment of the labor required to add together the wages of each particular workman.

Sometimes it is required to find the average of a series of observations arranged by groups. Let us assume that in the following table the observations are made only to the first decimal place.

TABLE 12

Group. (1)	Number in group. (2)	Average of group. (3)	Product of (2) and (3).
0–0.9	21	0 45	9 45
1 0–1.9	17	1 45	24 25
2.0–2.9	12	2.45	29.40
3.0–3.9	8	3.45	27.60
	58		58)90.70
			1.56 = average

The *geometric mean* of two numbers is the square root of their product. If we have two numbers a and b, the geometric mean is $\sqrt{ab}$. It is also called the *mean proportional* between two numbers, because if we let it be represented by x, then $a : x = x : b$, *i.e.*, a is to x as x is to b. By algebra, from this equation $ab = x^2$. $\therefore x = \sqrt{ab}$.

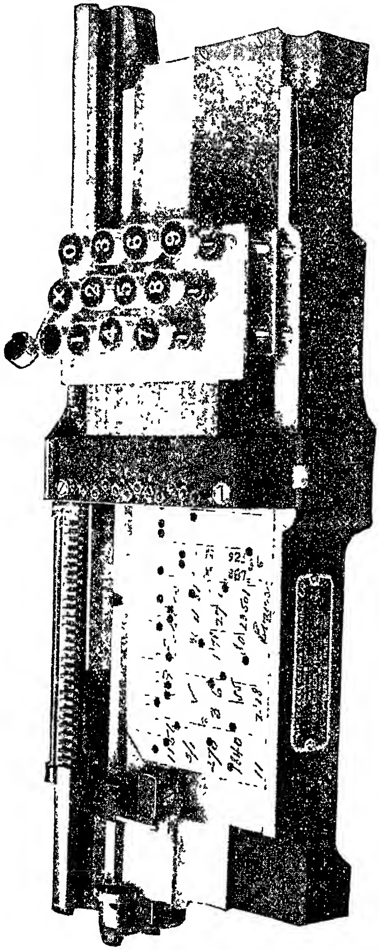


FIG. 5. — Machine for Punching Card.

If there are three numbers the geometric mean would be the cube root of the product of the three numbers; and so for larger numbers.

As compared with the arithmetic mean the geometric mean minimizes the effect of very large numbers and increases the effect of very small numbers on the final results. For instance, the arithmetic mean of 4 and 20 is $\frac{4+20}{2} = \frac{24}{2} = 12$. The geometric mean would be $\sqrt{4 \times 20} = \sqrt{80} = 8.95$. The arithmetic mean of 2 and 100 would be 51, the geometric mean 14.1.

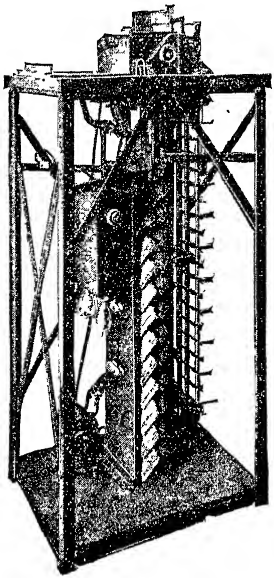


FIG. 6. — Machine for Sorting Cards.

Economists often use the geometric mean in combining the prices of different commodities to obtain an index of trade conditions. It has not been much used in demography, but there are places where it might well be used.

There is another kind of average known as the *harmonic mean.* A man travels two miles, the first at a rate of 10 miles per hour, the second at a rate of 20 miles per hour, what was his average rate of travel? The obvious answer, *i.e.*, 15 miles per hour, is not correct, for the man did not travel for two hours but for two miles. Actually he traveled the first mile in $\frac{1}{10}$ of an hour, or 6 minutes, and the second in $\frac{1}{20}$ of an hour, or 3 minutes. His average time, therefore, was $\frac{6+3}{2} = \frac{9}{2} = 4.5$ minutes per mile, and his average rate $\frac{60}{4.5} = 13.3$ miles per hour. The statistician seldom has occasion to use this. Algebraically the harmonic mean of two numbers, a and b, is $\frac{2ab}{a+b}$.

In the study of data arranged in series, the items of which fluctuate up and down but which nevertheless show cyclical variations, the *moving average* is often computed in order to obtain a series from which the local fluctuations have disappeared. The moving average is a series of averages, each based on the same number of items, but each group of items, as it advances, adding one new item and dropping one old one. If for example we have items in this order: — 16, 14, 18, 17, 18, 17, 19, 15, 13, 14, 11, 12, 10, 11, 8, the moving average based on successive groups of three items would be $\frac{16+14+18}{3} = 16$; $\frac{14+18+17}{3} = 16.3$; $\frac{18+17+18}{3} = 17.7$; $\frac{17+18+17}{3} = 17.3$; and so on. Sometimes groups of five items are taken, or nine, or twenty-one, but usually some odd number. An example of the moving average may be seen in Fig. 44. Some one has said that the moving average is so named because the large amount of work required moves one to tears. Any one thus affected should know that there are shortcuts to the results which may be found described in works on general statistics. The *moving median* might be used if the groups chosen contained many items. This would require somewhat less work than the moving average.

Mechanical devices for statistical work. — It would not do to close this chapter on statistical arithmetic without calling attention to the mechanical devices now available for performing the operations of addition, subtraction, multiplication and division. Where statistical operations are constantly going on these instruments more than pay for their cost. They are too well known to need description here.

The tabulating devices of the Hollerith and Powers types are not as well known, but they have become an established feature in the U. S. Bureau of the Census and in the statistical departments of large commercial and industrial corporations. Three separate devices are required for this work — a card punching machine, a sorting machine and a counting machine. In keeping records

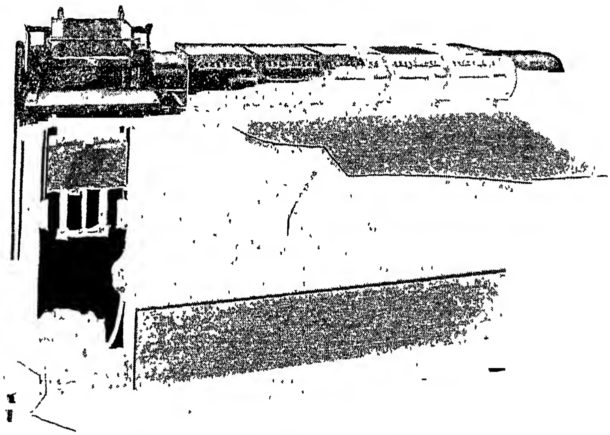


FIG. 7. — Machine for Counting Cards.

of deaths, the data from each death certificate are transferred to a card, each fact being indicated by number, a hole being punched in the proper column. These holes serve as the basis of sorting in the second machine. By feeding the cards into the sorting machine they can be quickly divided into piles according to age, or sex, or cause of death, or into other groups or classes. The third machine counts the cards.[1]

[1] Information concerning these devices may be obtained from the Tabulating Machine Co., 111 Devonshire St., Boston, Mass. The author is indebted to this company for figures 5, 6 and 7. Another form of tabulating and counting machine is sold by the Powers Accounting Machine Co., 50 Church St., N. Y., and 185 Devonshire St., Boston.

It is not necessary to explain all the abbreviations on this card, as any abbreviations may be used. But "NRs" stands for non-resident; "M" for male; "F" for female; "Wh" for white; "Ca" for Canada; etc.

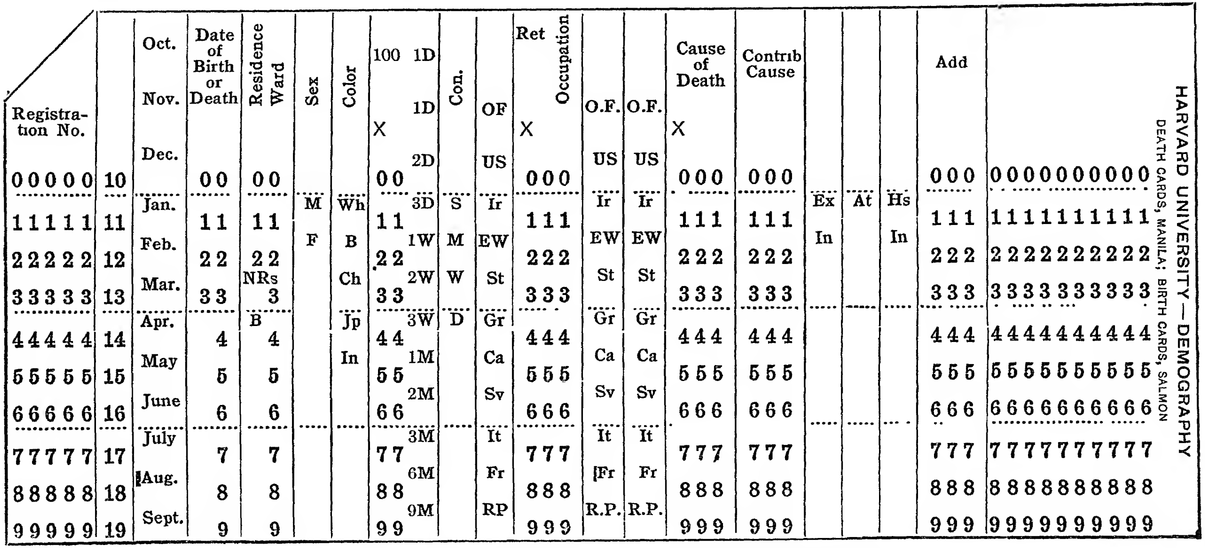


FIG. 8. — Card for Recording Data on Death Certificates.

(p. 55)

EXERCISES AND QUESTIONS

1. Define the following statistical units as used by the U. S. Bureau of the Census.

a. A family.
b. A birth.
c. A death.
d. An infant.
e. A dwelling house.
f. A colored person.
g. A farmer.
h. A cotton-mill operative.
i. An urban community.
j. A rural community.
k. The population of a place.
l. Communicable disease.
m. Suicide.
n. Age
o. A citizen.
p. An industrial accident.
q. A sleeping room.

2. Criticize the tables in the annual reports of any health department (as assigned by the instructor), as to title, form, boxing, abbreviations, etc.

3. Discuss the tables in the reports of the U. S. Bureau of the Census. Should they be taken as models?

4. Is it good form to use the following abbreviations?

a. "No. of Days," for Number of Days.
b. "Pop." for population.
c. "Av." for average.
d. "Ty. rate" for death-rate from typhoid fever.
e. "T. B. rate" for death-rate from tuberculosis.
What other ill-advised abbreviations have you observed?

5. In one ward of a city 517 births were reported, it being estimated, on the basis of past experience, that this figure was within 8 per cent of the true number; in a second ward the report was 730 births, with an estimated error of 20 per cent; in a third the corresponding figures were 910 and 25 per cent; in a fourth, 604 and 18 per cent; what was the probable number of births in the city? And what was the probable percentage error of the total number of reported births?

6. If the death-rate in a certain city was 20 per thousand in 1910, if it decreased 10 per cent the next year, increased 10 per cent the year after, decreased 20 per cent the next year, increased 20 per cent the next year, what was the death-rate in 1914?

7. Multiply the following numbers by the arithmetic process, by the use of logarithms and by the use of the slide rule. Note the relative accuracies of the result.

a. 17 × 215.
b. 95 × 847.
c. 2161 × 1050.
d 9230 × 40,373.
e. 10,072 × 736.
f 54,672 × 93,721.
g. 4 7 × 1573.
h. 0.231 × 1 29.
i. 0.507 × 0.062.
j. 432 1 × 13.41.

8. Similarly perform the following divisions:

a. 342 ÷ 17.
b. 9467 ÷ 872.
c. 473,561 ÷ 2395.
d. 100,262 ÷ 730.
e. 0.517 ÷ 2.43.
f. 20,073 ÷ 98.
g. 763 05 ÷ 40 39.
h. 8999 ÷ 1101.
i. 30,500 ÷ 10.07.
j. 0.03 ÷ 76.

9. Given the following items: Find the mean, the median, the mode, the upper quartile.

a. 6, 7, 6, 2, 8, 4, 9, 6, 7, 2, 1, 2, 1, 9, 8, 7, 3, 6, 6.
b. 71, 3, 2, 0, 0, 1, 9, 5, 6, 3, 0, 2, 7, 7, 0, 4, 0, 2, 8.
c. 2, 12, 2, 14, 3, 13, 9, 16, 1, 0, 40, 90, 3, 22, 7, 15.

10. Arrange each of the sets of figures in the last question in groups as follows and find the average of each set from these groups.

	(1)	(2)	(3)	(4)	(5)
Group limits (inclusive)	0–4	5–9	10–14	15–19	20 etc.
Number of items in group	..	.	...	.	

11. Find the arithmetic and geometric means of:

a. 71 and 19. *b.* 421 and 7. *c.* 21, 7 and 11.

CHAPTER III

STATISTICAL GRAPHICS

Use of graphic methods. — Statistics are numerical expressions of facts. When the facts are few in number it is not necessary to use figures to represent them, but as the number of facts becomes larger a point is reached where memory of individual facts must be supplemented by generalizing them, by letting a number stand for a class or a group of facts. In the same way when the numerical processes become complicated, when the figures become unwieldy or attain magnitudes beyond the ordinary range of familiarity, it is useful to resort to another process and represent the figures graphically. And even when the facts are few and simple their representation by diagram is often a distinct aid to the mind in grasping their meaning and fixing them in the memory.

There are two distinct uses of graphic methods and it is important to keep these in mind in preparing diagrams. The first use is for study. The relations between different groups, classes and series of facts can often be understood better from diagrams than from tables of figures. By the use of cross-section paper it is possible to interpolate values between plotted points, to generalize the facts of a series in which the data are more or less irregular, to extend plotted curves ahead of the data, thus enabling statistics to be used as a basis of prediction, to compare different curves and thus establish correlations. Properly used graphic methods will greatly assist the statistician in understanding his data. It is a great mistake, however, to think that all statistics should be reduced to diagrammatic form, and it must be remembered that not one person in ten is able to read a complicated diagram understandingly. Some regard diagrams as puzzles to be worked out. To such persons diagrams are of little or no practical value.

The other use of graphic methods is for displaying the facts in such a way that they will attract attention, that the general results, regardless of details, will fix themselves in the memory. This use of graphic methods has greatly increased in recent years. We see diagrams of all kinds on bill-boards, in advertisements, in public health reports, in popular and scientific articles, even in moving pictures. The growing importance of the whole subject is shown by recent publications. The first of these was a notable book by W. C. Brinton[1] on Graphic Methods for Presenting Facts, which contains several hundred different kinds of graphic representations. A joint committee on standards for graphic presentation, composed of representatives of various associations of national scope has been organized to consider the subject.[2]

Thus, on the one hand, we have the diagram forming a part of mathematics, and, on the other hand, we find it merging into the cartoon; hence we may lay down the general principle that graphic methods of depicting statistics must be selected according to the use to which they are to be put.

Types of diagrams. — The word *diagram* may be used in a generic sense to include all of the various kinds of mathematical graphs, plots, charts, maps and pictorial illustrations used by statisticians for the display or comparison of numerical data. These may be roughly classified as follows:

1. One-scale diagrams, in which different items are compared with each other on the basis of a single magnitude scale.

[1] See list of references in Appendix.

[2] Copies of a preliminary report may be secured from the Am. Soc. Mech. Eng., 29 West 39th St., New York City.

2. Two-scale diagrams, commonly known as graphs, in which two magnitudes are involved. One of these is commonly represented by a horizontal scale and one by a vertical scale. These graphs take many forms.
3. Three-scale diagrams. It is difficult to represent three dimensions on a flat sheet of paper, but it is sometimes done by the so-called isometric method.
4. Component-part diagrams, in which a single quantity is shown in sub-division.
5. Pictorial diagrams, or pictograms, a special form of the one-scale diagram used for display.
6. Statistical maps, or cartograms, a special form of the two-scale diagram, in which one scale is area arranged geographically, while the other consists of differently colored or shaded areas.

There are also many miscellaneous types of diagrams with specially devised irregular scales, logarithmic scales, probability scales, etc., and with one scale superposed on another. These are for study and not for display.

The appeal to the eye. — Diagrams are intended as an appeal to the eye, and advantage is taken of the ability of the eye to observe quickly and with fair accuracy:

(*a*) *Distances,* as, for example, the relative heights of different points above a base line or the relative distances of points from some other point or from some axis.

(*b*) *Areas,* as shown by comparison of similar figures, that is by circles, squares, rectangles or even irregular figures.

(*c*) *Volumes,* as shown by comparison of similar cubes, cylinders, spheres and irregular figures.

(*d*) *Ratios,* such as the relative lengths of parallel lines, areas or volumes similar in general shape.

(*e*) *Slopes*, or the relative inclinations of different lines from a base line.

(*f*) *Angles*, as shown by the sub-division of the 360 degrees about a point.

(*g*) *Shades and colors*, as shown by areas on pictograms and maps.

Graphical deceptions. — In preparing diagrams it is well to bear in mind that the eye may be deceived. There may be graphical fallacies as well as statistical fallacies. Some of these may be illustrated by well-known optical illusions.

In Fig. 9 the line *A* appears to be longer than *B*. In reality they have the same length. The shaded area *D* appears to be taller than *C*. In reality they have the same height. Astigmatism is also the cause of optical illusions. Those whose business it is to prepare diagrams for display should study these optical conditions.

But there are other and more important ways in which diagrams may deceive.

In pictograms we sometimes see two objects of different size — say two men, one large and one small, illustrating the relative numbers of persons who have died from two diseases. If the relative numbers are as 2 is to 1, the figures would naturally be drawn with the heights in that ratio. But to the eye the larger man would appear to be more than twice the size of the smaller one, because the eye would here judge not the height alone, but the whole area of the figure This very common fallacy in which one dimension is used for plotting, with no reference to the other dimensions which automatically changes, may be illustrated by the two circles *E* and *F*. The diameter of *F* is only twice that of *E*, but the circle *F* seems to be much more than twice as large as *E*. This fallacy may be called that of plotting by line and seeing by area.

Similarly when a polar diagram is made to illustrate the seasonal distribution of some disease, the number of cases per 1000 persons being indicated by the distance of each plotted point from the center, an incorrect idea is obtained. In Fig. 21 the death-rate for April and May

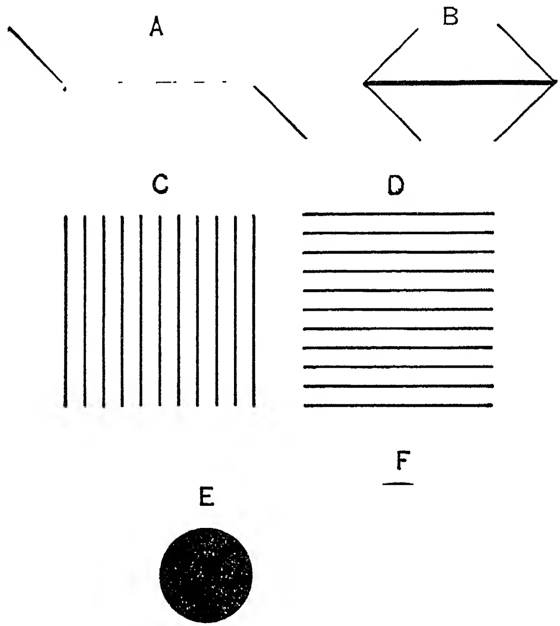


Fig. 9. — Optical Illusions.

was in reality only three times that for August and September, but from the diagram it looks to be more than three times as much. The reason is that the diagram was drawn as a line diagram, but the eye sees the area as well as the lines and the area embraced by the enveloping lines increases as the points become farther from the center.

Other fallacies connected with the choice of scales will be pointed out in the consideration of that subject.

Essential features of a diagram. — Every diagram, save the very simplest, should have a title; one or more scales, plainly indicated; a background of cross-section, or coordinate lines; the points, lines or areas representing the data plotted, marked for identification; and any necessary notes or explanations. As a rule diagrams should be self-contained, that is, they should tell the facts without regard to the accompanying text.

The title may be entirely outside of the frame of coördinate lines, with the idea that if the diagram is published the printer will set up the title in type. This simplifies somewhat the construction of the diagram, but if a lantern slide is made it may be that the printer's type will be found to appear disproportionately small. If the title is placed within the frame of coördinate lines these lines must be discontinued and not allowed to run through the letters of the title. On machine-ruled paper this rule cannot hold as the coördinate lines cannot be erased. It is possible to place the title on a piece of white paper and paste it over the cross-section lines. In the case of machine-ruled tracing cloth, the lines may be removed by the use of xylol, or gasolene, and a clear background obtained for the title.

In designing the title it is not necessary to use the words "Diagram showing the . . . " any more than it is necessary to say "Table showing the . . . ."

The size and shape of the diagram will depend in great measure upon the scales chosen, but as diagrams are very often reproduced, even though not drawn primarily for publication, it is always well to prepare them as if for publication.

For the purposes of a typewritten report, diagrams should be kept within the limits of a rectangle 7 by 9½ in.

The standard typewritten paper is $8\frac{1}{2} \times 11$ in., but there should be margins of 1 in. on the top and left and $\frac{1}{2}$ in. on the bottom and right for binding and trimming. The paper containing the diagram should be cut $8\frac{1}{2}$ by 11 in. Larger diagrams may of course be desirable or necessary.

For reproduction most diagrams have to be reduced in size. When this is done the diagram as a whole is not only made smaller but the letters are made smaller and every line made thinner. Care should be taken therefore that the letters and figures used are not too small and that the lines are not too thin.

As a rule letters and figures should be so placed that they can be easily read from the bottom or the right-hand edge.

The coördinate lines are used to guide the eye and to enable one to read from the scale with accuracy and minuteness. For display purposes, however, no more coördinate lines should be used than are necessary, as too many are confusing. The coordinate lines should be lighter in weight than the plotted points or lines in order that the latter may stand out conspicuously.

Too many plotted lines should not be used in the same diagram as confusion may result. If there is more than one plotted line each should be clearly marked. This is especially important if the lines cross or meet at any point.

Often it is desirable to have the diagram include within its boundaries not only the graphic representation of the figures, but the figures themselves.

One-scale diagrams.—The simplest diagram is one where the magnitudes of the different items are represented by the relative lengths of lines or by narrow rectangles of constant width. They are easy to understand and are useful for many purposes. The magnitudes represented by the lines may be stated in figures or there may be a scale shown for comparison. See Figs. 10 and 11. The lines may be drawn horizontally or vertically.

An important principle in line diagrams is that all of the lines should start from the same base. If this is not done comparison is difficult. In the case of Fig. 11, which shows the birth-rates and death-rates for two European countries,

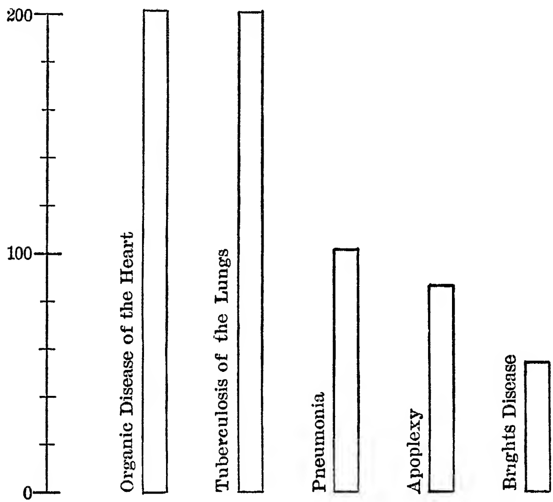


FIG. 10. — Numbers of Deaths from Five Most Important Causes. Cambridge, Mass., 1915.

it is easy to compare the births, shown by the total lengths, and the deaths, shown by the black, because they start from the left-hand line, but it is difficult to compare the natural increase of population in the two countries, shown by the white, because they have no common base. If the natural rate of increase is important it is better to use separate lines for births, deaths and increase as shown in Fig. 11, *c* and *d*.

It is also difficult to compare two lines which, though they have a common base, extend in opposite directions from the base. This, however, is often done with a fair degree of satisfaction. See Fig. 42.

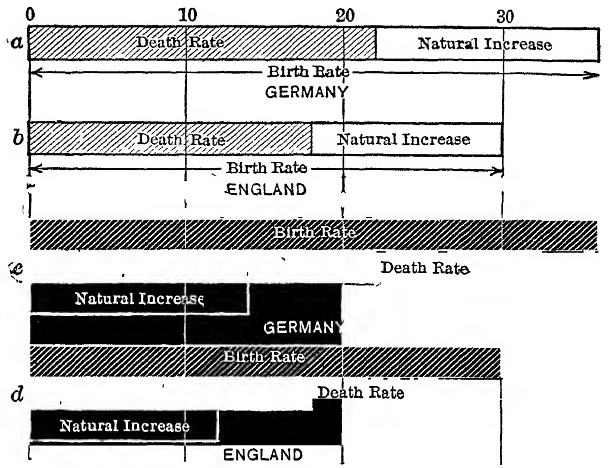


FIG. 11. — Comparison of Birth-rates, Death-rates and Rates of Natural Increase.

Diagrams with rectangular coördinates. — Most of the diagrams used to illustrate statistics are of the two-scale type. There is a horizontal scale with magnitudes increasing from left to right and a vertical scale with magnitudes increasing from bottom to top. It is customary also to rule in a sort of checker-board consisting of parallel vertical and horizontal lines to guide the eye in following the scales across the paper. To further assist the eye heavy lines are used for the round numbers of the scale and finer lines for sub-divisions. It is good practice also to always use for the zero line a line as heavy as the plotted line. Usually this would be the bottom line and the left-hand line. If there be no zero, as in the case of a scale of years, the heavy line would not be used. In the case of percentage diagrams both the zero per cent line and the hundred per cent line should be heavy. The numerical values for the sub-divisions of the scale are shown in figures, preferably at the bottom and left side of the diagram. Sometimes they are placed also at the top and right. Thus the zeros of both scales are supposed to be at or near the lower left-hand corner; but circumstances may compel some different arrangement.

In diagrams of this kind *time*, whether in years, months or days, is generally expressed by the horizontal scale and always runs from left to right. Such diagrams are sometimes called historigrams, sometimes merely graphs.

The distances measured along the vertical scale are known to mathematicians as *ordinates*, the distances on the horizontal scale as *abscissae*.

There are several ways of plotting with two scales. One way is to use the vertical scale as a measure of the length of certain vertical lines, each of which represents the magnitude of an item, and to use the horizontal scale to indicate the occurrence of the item. Thus in Fig. 12 we have a daily record of the rainfall for one month. Each rainfall is represented by a line of appropriate length, the position of the line showing when the rain occurred. This method is especially adapted to events which occur intermittently, and without regular gradations, that is to discrete series.

The rainfall data might have been indicated by dots, or crosses placed at the tops of the lines, the latter being left out. This would be misleading, however, unless similar dots or crosses were placed on the zero line for the days of no rainfall. This would not look well, and it is never done.

The vertical line method or *ordinate plotting* is sometimes used for plotting data in series, the horizontal scale representing time. Thus we may compare the death-rates for different years by a diagram such as that shown in Fig. 13 *A*. This, however, is a continuous series and may be plotted

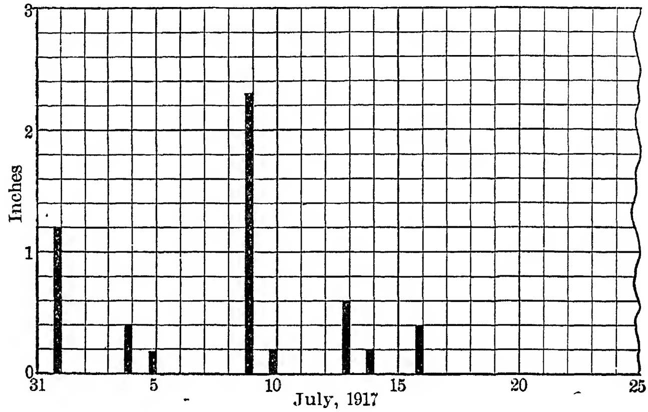


FIG. 12 — Example of Plotting a Record of Rainfall.

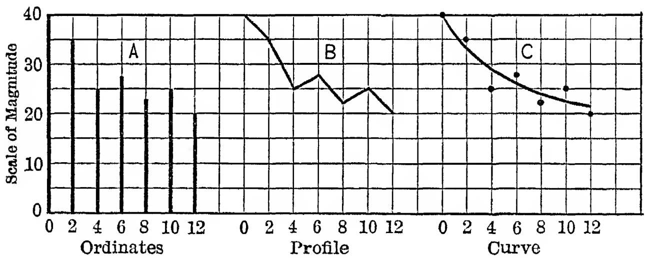


FIG. 13. — Example of Simple Plottings.

as a broken line, known as a profile line, which shows continuity. See Fig. 13 *B*. For most purposes this profile method is to be preferred to the vertical line method, but the latter is perhaps understood better by persons not familiar with graphic methods.

Still another way would be to plot the data as dots, or crosses, and draw a smooth curve through them to show the trend of events. This implies that the data are subject to errors and that the smooth curve gives a better picture of the true events. See Fig. 13 *C*. The art of smoothing curves is described in most books on statistical technique. In general it may be said that the rules usually laid down are based on the laws of probability.

Use of the horizontal scale. — In the illustrations just given and in many which are to follow the divisions of the horizontal scale are taken to be definite points of time, namely days and years, each point being plotted directly on a vertical line. This does very well for plotting yearly records which run on continuously, and there is no objection to the method for practical purposes. In fact it is the common method. It is not, however, strictly accurate; for a year is not a point of time, but an interval of time. The logical way is to let the space between the lines represent the year, the vertical lines marking the boundaries. Graphs are often made on this basis.

TABLE 13

NUMBER OF DEATHS: EXAMPLE FOR PLOTTING

Month.	Deaths.	Month.	Deaths	Month.	Deaths.	Month.	Deaths.
(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
Jan.	40	Apr.	27	July	20	Oct.	17
Feb.	30	May	23	Aug.	17	Nov.	20
Mar.	25	June	25	Sept.	15	Dec.	25

Here the problem is to divide the horizontal scale, which represents a year, into twelve parts, each of which represents a month, and plot one point for each month. Now we get

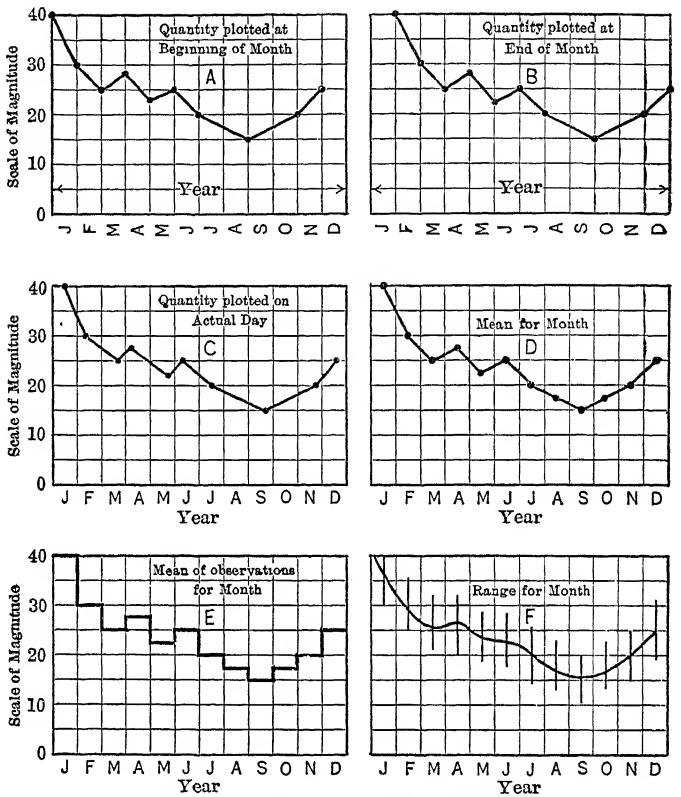


Fig. 14. — Examples of Time Plotting.

into trouble if we plot the data on the lines, for we might do this in two ways, as in Fig. 14, *A* and *B*. In one case we plot the point at the beginning of the month, in the other, at the end of the month. Of the two the latter is to be preferred. It would be more logical to plot the points in the middle of the spaces as in Fig. 14, *C* or *D*. If the figures plotted represent the monthly averages of several items occurring in each month the method of plotting shown in Fig. 14 *E* is a proper one. Fig. 14 *F* shows how one may plot the mean as well as the maximum and minimum item for each month. At present there is no well-established custom in regard to these methods. Plotting on the line is usually followed simply because it is easier and makes a neater diagram. Its illogical character seldom causes serious misunderstandings.

Plotting figures by groups. — The plotting of individual observations is comparatively easy; but it is difficult to decide how to plot the totals and means of groups, and still more difficult if the groups are irregular. This can best be appreciated by an example. Let us undertake to plot the following data:

TABLE 14

DATA TO BE PLOTTED

Age (last birthday).	Number of cases.	Age group.	Number of cases in group	Average number of cases for each year
(1)	(2)	(3)	(4)	(5)
0	1			
1	2			
2	2	0–4	12	2.4
3	4			
4	3			
5	1			
6	4			
7	3	5–9	15	3.0
8	5			
9	2			
10	6			
11	4			
12	7	10–14	25	5.0
13	5			
14	3			
15	4			
16	6			
17	5	15–19	20	4 0
18	3			
19	2			

If we plot the individual items we have the result shown in Fig. 15 *A*. If we plot the total numbers of cases in each group we may do so by the methods *B*, *C*, or *D*. In these the horizontal scale represents not individual ages, but groups. We may indicate this fact by using the hyphens as shown. In *B* we have plotted the figure 12 on the line which indicates the maximum limit of the group 0–4, 15 on the line which indicates the maximum limit of group 5-9, etc. In *C* we have plotted 12, 15, etc., in the middle of the spaces which represent the groups. In *D* the height of the horizontal line above the base is taken to represent the total and extends across the group limits. If we wish to show both the individual observations and the means for the groups we may plot as in *E*.

In plotting by groups care should be taken to make it clear that the horizontal scale stands for groups and that the vertical scale stands for the number in the group.

Plotting irregular groups. — Let us now take the case of irregular groupings. Assume the following data:

TABLE 15

DATA TO BE PLOTTED

Age group.	Number of cases in group.	Average for each year in group.
(1)	(2)	(3)
0– 4	4	0 8
5– 9	6	1 2
10–14	8	1 6
15–19	6	1 2
20–29	7	0 7
30–39	5	0.5
40–59	8	0.4
60–79	6	0 3
80–99	3	0.15

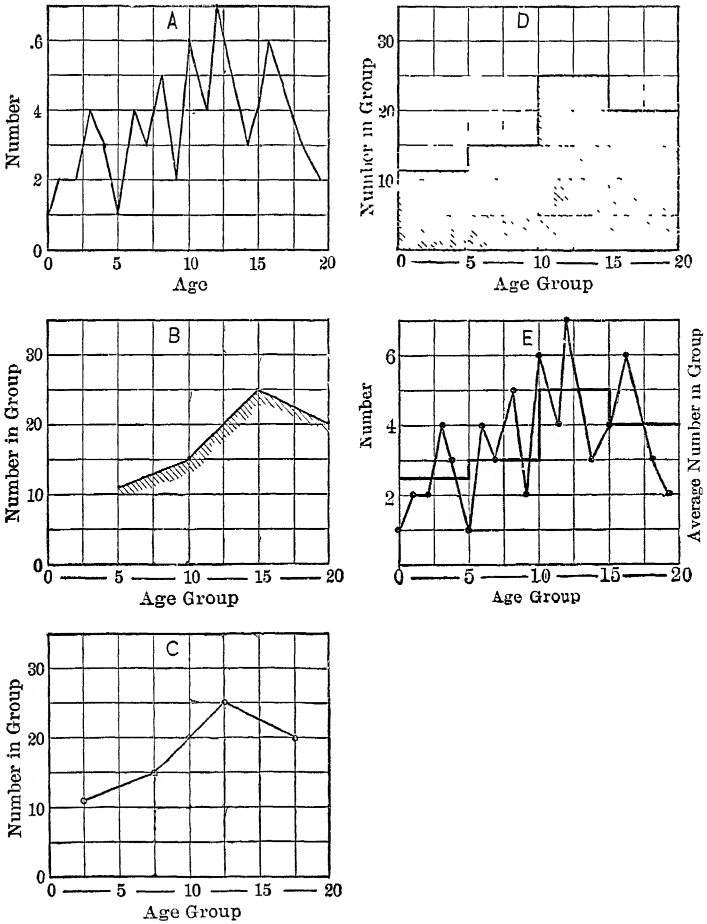


FIG. 15. — Examples of Age Plotting.

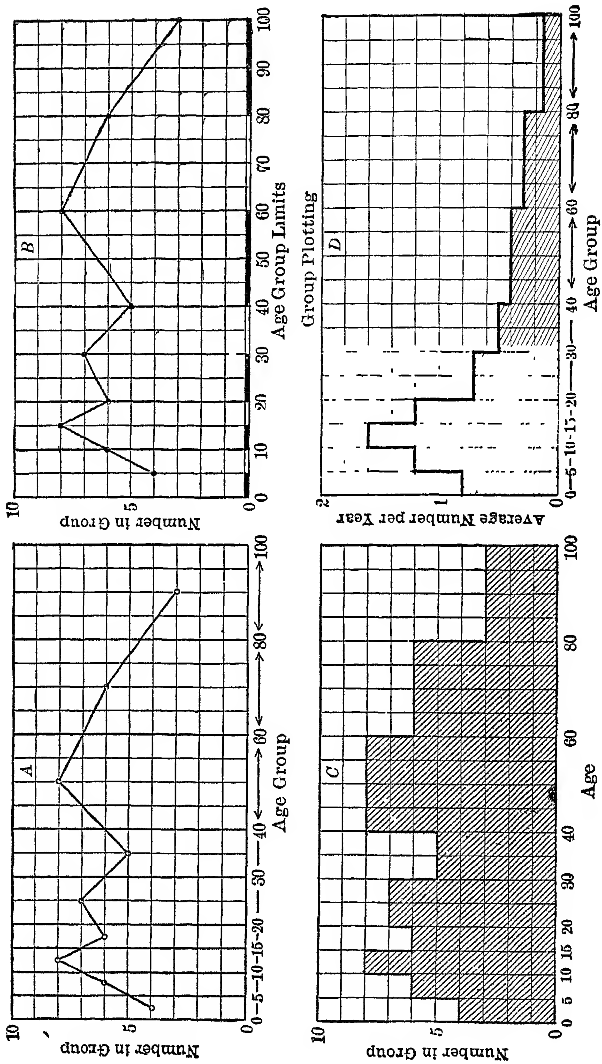


Fig. 16. — Examples of Group Plotting.

In the first place we must find some way to indicate to the eye the varying intervals of the group. The first four groups cover five years, the next two ten years and the last three twenty years each. We might do this as in Fig. 16 *A*, in which the heavy vertical lines indicate the group limits. In *B* the coördinate lines are regular and the group limits are shown by the emphasized horizontal scale. In *C* the blocks indicate the group limits. Not one of these, however, gives an adequate picture of the distribution of the cases according to age, because the groups are not uniform. All three diagrams are fallacious because the ordinates are not strictly comparable. The best way to show distribution by age is to make the groups comparable by reducing all to a common denominator. This can be done by finding the average number of cases for each year in the group. The results are shown in Fig. 16 *D*. Here the irregular grouping on the horizontal scale is maintained, yet a good idea is given of the distribution of the cases according to age.

Summation diagrams. — For many purposes it is desirable to plot the results obtained by the successive summation of the items in preceding groups. This gives what are called summation diagrams, cumulative plots, mass plots or mass curves. This may be illustrated by the data on p. 77.

These data are plotted in Fig. 17. Sometimes instead of connecting the plotted points by straight lines a curved line passing approximately through them is sketched in. It should be noticed that in this diagram the horizontal scale stands for age and not for age-groups.

One use which can be made of a plot of this kind is to find the median of the series. There are 53 cases in all. The middle one is the 27th. From the scale this item has a value of 24 years, as shown by the cross. In the same way the quartiles may be found and the decentiles.

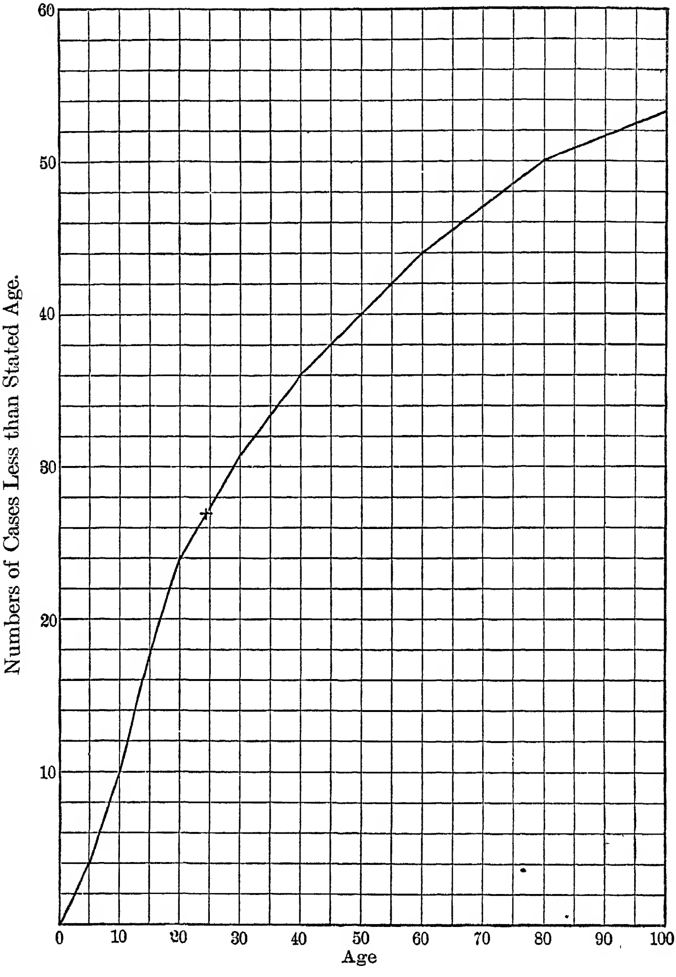


FIG. 17. — Example of Cumulative, or Summation Plotting.

TABLE 16

DATA TO BE PLOTTED

Age-group	Number of cases.	Summation group.	Age.	Number of cases less than stated age
(1)	(2)	(3)	(4)	(5)
0–4	4	0–4	—	—
5–9	6	0–9	5	4
10–14	8	0–14	10	10
15–19	6	0–19	15	18
20–29	7	0–29	20	24
30–39	5	0–39	30	31
40–59	8	0–59	40	36
60–79	6	0–79	60	44
80–99	3	0–99	80	50
Total	53		100	53

Another use is that of redistributing the cases according to a different age-grouping. Let us suppose that we desire to find the number of cases between the ages of 35 and 45, *i.e.*, in age-group 35–44. From the vertical scale and the plotted curve we find that there are 38 cases below age 45 and 33 cases (approximately) below age 35, hence there are 38 − 33 = 5 cases in age-group 35–44. This principle may be usefully applied in redistributing the population of a city into age-groups in connection with the computation of specific death-rates.

Choice of scales. — The choice of both scales is a matter of great importance, for it not only influences the size and shape of the diagram, but controls the slopes of plotted lines and the apparent differences between plotted points. In Fig. 18 we have the death-rates of Moscow from 1881 to 1910 plotted by five-year groups according to two different scales. The two diagrams look to be quite different, and *B* gives the impression of a greater decrease in rate than *A* because on account of the greater vertical scale and the smaller horizontal scale the slope of the plotted line is more.

Sometimes for purposes of comparison two lines are plotted on the same sheet, each having its own vertical scale. Here the choice of the proper scale is all-important.

It sometimes happens that in order to show the desired variations in a series of plotted ordinates a scale must be chosen so large that the zero point would fall too far below the plotted point to have it appear on the diagram. Right here lurks a graphical fallacy which may be serious. It is best appreciated by studying an actual illustration.

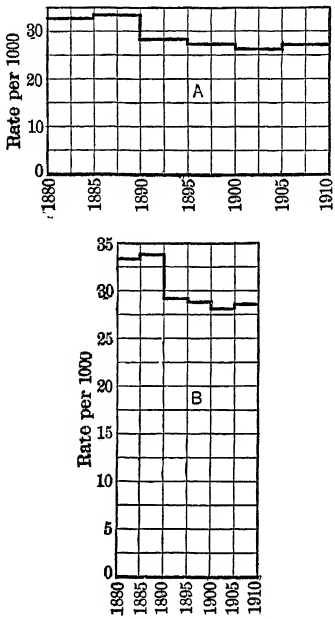


FIG. 18. — Death-rates: Moscow, 1881–1910. Showing Effect of Changing Scales.

Fig. 19 shows the general death-rate and the tuberculosis death-rate per 1000 inhabitants in Boston, Massachusetts, from 1881 to 1911, the figures being plotted in five-year groups. In *A* different scales are used and the scales do not extend to zero on the base line. In *B* the same scale is used for both series of items. From diagram *A* one would get the idea that the tuberculosis rate was decreasing much faster than the general death-rate, but from diagram *B* the opposite idea would be obtained.

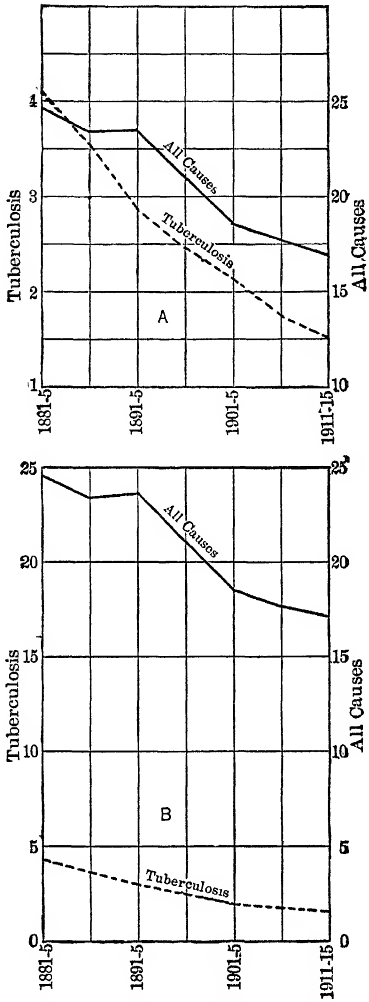


FIG. 19. — Comparison of Deaths from Tuberculosis with Deaths from all Causes: Boston, Mass. A, Incorrect Method. B, Correct Method.

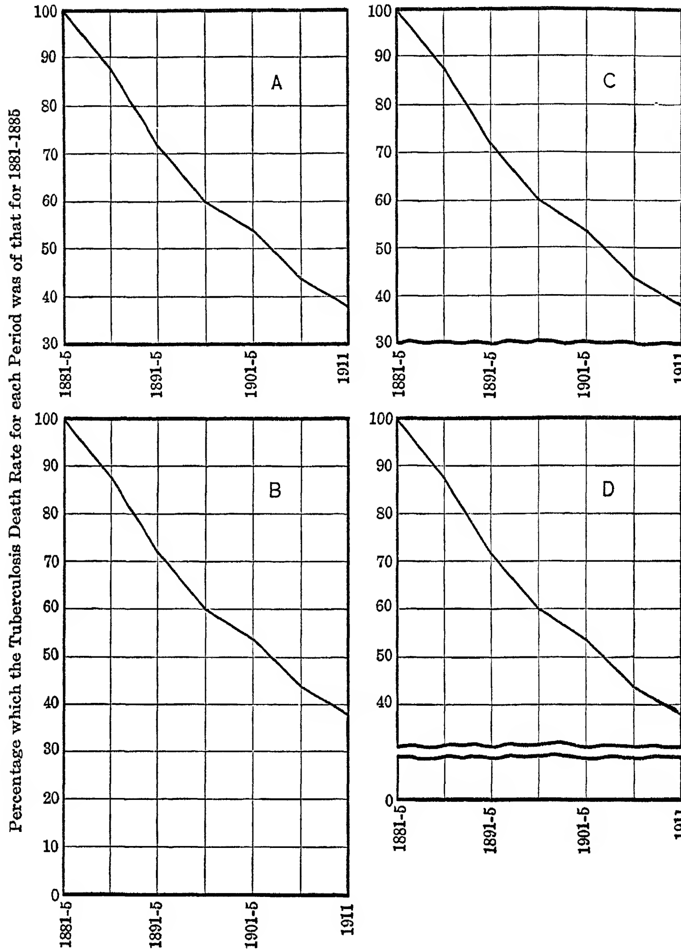


FIG. 20. — Example of Not Carrying Scale to Base Line. Tuberculosis Death-rate: Boston, Mass.

Fig. 20 shows the reduction of the tuberculosis death-rate in Boston expressed in terms of the percentage which the death-rate of each period was of that for the period 1881 to 1885. In *B* the vertical scale is carried down to 0 per cent at the base line. This gives a true picture of the reduction which has taken place and the death-rate remaining. In *A* the vertical scale is not carried to the base line and the diagram gives the optical impression that the reduction has been greater than it actually has been and that the rate at the end of the period was very much less than at the beginning. Brinton has suggested that when the base line does not represent the zero of the vertical scale it should be drawn as a wavy line instead of a straight line, and this idea has much merit. Where two different vertical scales are used, and one goes to zero at the base line while the other does not, the wavy line may extend only half way across the diagram from that side of the diagram where the scale does not go to zero. *C* in Fig. 20 illustrates the appearance of a diagram drawn in this way. The wavy line implies that the lower part of the diagram is omitted. The form shown in *D* is even better.

Diagrams with polar coördinates. — Fig. 21 illustrates a diagram with the ordinates represented by distances from a central point along radial lines, the abscissæ, if we may use the term out of its place, being represented by the angle which the ordinate makes with the vertical measured clockwise around the circle. This form of plotting has a limited application and because of its inherent fallacious character should be abandoned.

Double coördinate paper. — Sometimes it is convenient to use what may be called double coördinate paper. This is illustrated by Fig. 22. Here the plotted line may be read against either set of coördinates. The horizontal lines give the number of deaths from typhoid fever, the scale being at the left. The inclined lines give the death-rate per 100,000. Thus in 1900 the number of deaths was about 305, the death-rate about 27 per 100,000. The slope of the inclined lines depends upon the increase in population. The black inclined line represents population and this may be read for the censal years from the right-hand scale. It will be seen that the ratio between

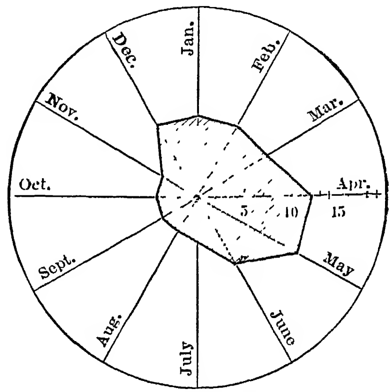


FIG. 21. — Example of Radial Plotting.

the right-hand and left-hand scale for any horizontal line gives the rate for the heavy line, *i.e.*, 200 ÷ 1,000,000 = $\frac{20}{100,000}$, or 20 per hundred thousand. So also 100 ÷ 500,000 = 20 per hundred thousand. Any point on the heavy line, therefore, gives a rate of 20 per hundred thousand. The rate line for 10 per 100,000 is one-half way to the line between the heavy line and the zero or base line, on each vertical line which represents a census. The rate line of 30 is, on each vertical, as far above the black line as the rate line of 10 is below it. And so on.

In the example chosen the typhoid fever rate in Brooklyn has fallen since the date of the last plotting, *i.e.*, 1906.

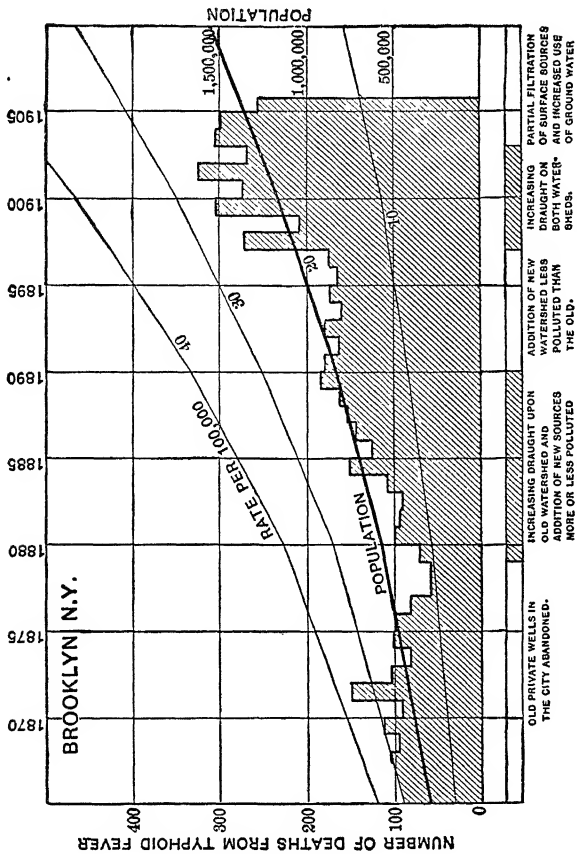


Fig. 22. — Diagram Showing the Number of Typhoid Fever Deaths and the Corresponding Death-rates in Brooklyn, N. Y.

Semi-logarithmic cross-section paper. — Thus far we have been dealing with regular scales in which the intervals are uniform from one end to the other. It is possible to construct scales with intervals which are not uniform, but which vary in a systematic way. These are used for special purposes. The most common scale of this kind is the logarithmic scale.

Diagrams in which the vertical scale is logarithmic and the horizontal scale uniform are sometimes called "ratio charts." These have been used by engineers for many years, but they are only beginning to be appreciated by statisticians.

It will be recalled that the logarithms of the decimal numbers are as follows:

TABLE 17

LOGARITHMS OF NUMBERS

Number.	Logarithm.
(1)	(2)
1	0 000
10	1 000
100	2 C00
1,000	3 000
10,000	4 000
100.000	5 000
1,000,000	6 000

As each number increases tenfold the logarithm increases by one; and in general it may be said that as numbers increase at a regular *rate* the logarithms increase by a regular increment. From the logarithm tables[1] it may be seen that the log of 10 is 1.0000, and that if 10 is increased by 25 per cent and becomes 12.5 the log of 12.5 is 1.0969, an increment of 0.0969. The log of 50 is 1.6990. 50 increased by 25 per cent is 62.5. The log of 62.5 is 1.7959, an increment of 0.0969 as before. The log of 1570 is 3.1959. 1570 increased by 25 per cent is 1962.5 and the log of this is 3.2928, an increment of 0.0969 as before. If, using a uniform scale, we plot figures which increase at a constant rate we shall get a curve as shown in Fig. 23 *A*. Let us

[1] See Appendix.

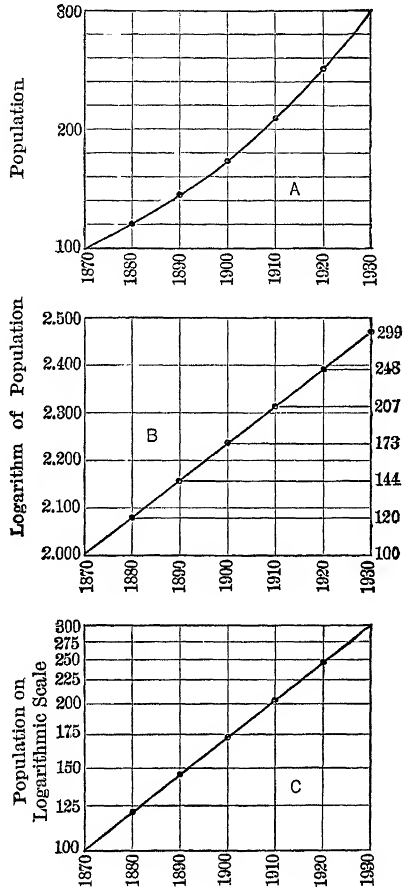


Fig. 23. — Example of Logarithmic Plotting.

start with a population of 100 in 1870 and assume an increase of 20 per cent each decade. We then have the following:

TABLE 18

DATA TO BE PLOTTED

Year.	Population	Log of population
(1)	(2)	(3)
1870	100	2 0000
1880	120	2 0792
1890	144	2 1584
1900	173	2 2380
1910	207	2 3160
1920	248	2 3945
1930	299	2 4757

The figures in column (2) are plotted in *A*. If we plot the logarithms of the numbers in column (2) we have a straight line as in *B*. This being so, why not label the horizontal lines with the numbers in column (2) instead of their logarithms? This is done at the right of the diagram. It will be seen that the vertical scale is not made up of uniform intervals, but aside from that fact it is a perfectly good scale. In *C* we have a diagram in which the vertical scale (represented by the horizontal lines) is drawn on this basis, and it will be seen that the figures in column (2) plotted on it fall in a straight line. This is a single logarithmic, or in simpler words, a ratio chart. Figures increasing at a constant rate plot out as a straight line on paper thus ruled, *i.e.*, with a uniform horizontal scale and a logarithmic vertical scale.

There are two uses for semi-logarithmic paper. One is to show variations in rate. If we plot the population of the United States on ordinary cross-section paper with uniform scales we obtain an ascending curve, but from this we get no idea of the constancy of the rate of increase. This is shown in Fig. 24 *A*. But if we use semi-log cross-section paper, as in *B*, we find that the rate of increase was constant from 1790 to 1860, but that since the Civil War the rate has been nearly constant yet not as great as before. On this paper equal slopes mean equal rates of increase, while on uniform paper equal slopes mean equal increments. Examples of the use of semi-log paper in plotting death-rates will be found on later pages.

Another use is that of enabling us to plot on one sheet observations which cover a very wide range. If we were using a uniform scale to plot such figures we should have to make the scale so small that individual differences between the small numbers could not be discerned. It will be noticed that on the semi-log paper the intervals for the small numbers are larger than for the high numbers, so that if plotted on this paper we can still read differences in the lower part of the scale. The upper part of the scale is foreshortened. In fact we can discern the same percentage differences in all parts of the scale.

Warning must be given against the too frequent use of semi-log paper. Because of its unequal scale divisions it is not well understood by the general public. It is a plotting paper which should be used for study rather than for display. It is not well adapted to the plotting of vital statistics by months, because it is not the rates of change according to seasons which interests us, but the actual changes. It must be remembered that semi-log paper is ratio-paper.

Logarithmic cross-section paper. — By logarithmic cross-section paper we usually mean paper on which both the horizontal and the vertical scales are logarithmic. Here the ratios are in both directions. It will be observed that

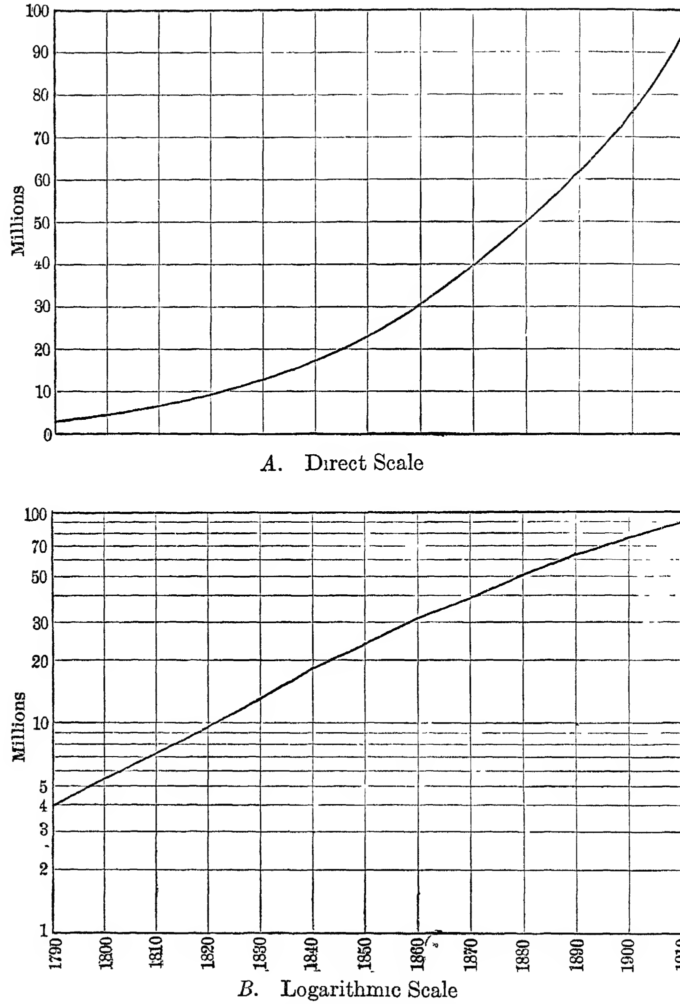


FIG. 24. — Population of the United States shown by Direct and Logarithmic Plotting.

the interval from 1 to 10 is the same as that from 10 to 100, from 100 to 1000 and so on. One objection to the logarithmic scale is that it does not go to zero. The interval below 1 runs from 1 to 0.1, the next from 0.1 to 0.01, the next from 0.01 to 0.001 and so on.

This paper is very largely used in scientific work, but its use for statistical purposes is somewhat limited.

Ruled paper. — It is not difficult to rule your own cross-section paper, although it is tedious work. Many sorts of ruled papers are on the market and can be purchased from dealers in engineering drawing materials.[1] The following scales are convenient for ordinary work:

(*a*) Inches subdivided into tenths in both directions.

(*b*) Half inches subdivided into tenths in both directions.

(*c*) Inches subdivided into tenths in one direction and into twelfths in the other direction, — useful for plotting data for the twelve months of a year.

(*d*) Semi-log paper, with inches subdivided into tenths in one direction, and with a logarithmic scale from 1 to 10,000 in the other direction.

(*e*) Arithmetical probability paper.

(*f*) Logarithmic probability paper.

(*g*) Paper with horizontal scale ruled for the calendar year, and vertical scale in inches subdivided to tenths.

It is possible to buy tracing cloth ruled in cross-section form, but the kinds of ruling are limited. Such cross-section tracing cloth is sold by the yard, width about 26 in., and may be cut to sheets of desired size.

Mechanics of diagram making. — For making diagrams it is advisable to provide a regular draughtsman's equipment. This should include:

(*a*) A drawing board of appropriate size. For small diagrams a size of about 12 in. by 17 in. is satisfactory.

[1] Such as the Codex Company, 119 Broad St., New York.

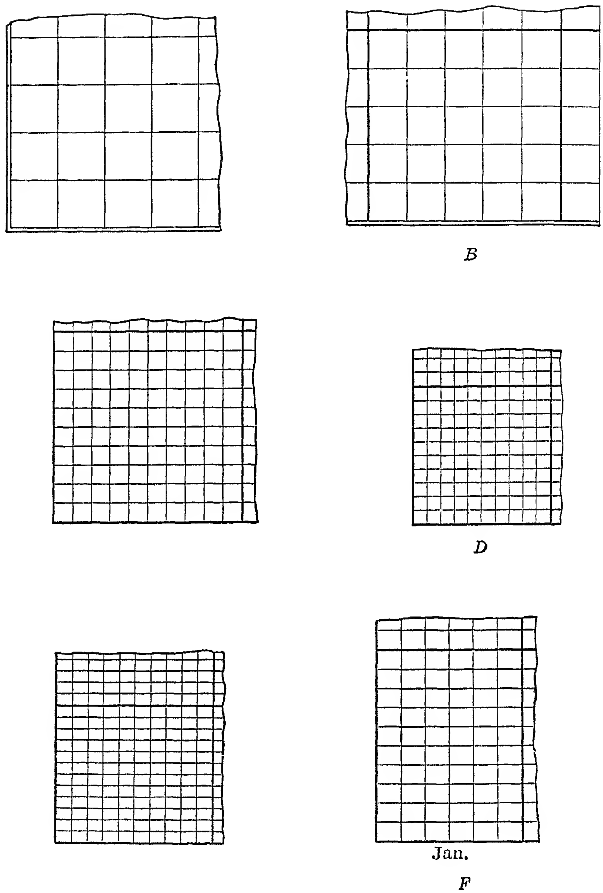


FIG. 25. — Examples of Plotting Paper. Sheets $8\frac{1}{2} \times 11$ inches.

(*b*) A tee-square long enough to extend across the drawing board.
(*c*) A 30-degree triangle, 10 in. long, celluloid.
(*d*) A 45-degree triangle, 6 in. long, celluloid.
(*e*) A lettering triangle, to give slopes for letters.
(*f*) A ruling pen.
(*g*) One or more scales, steel, celluloid or boxwood, variously ruled in tenths, quarters, etc.
(*h*) Black drawing ink (Higgins).
(*i*) Thumb tacks.
(*j*) Brown " detail " paper.
(*k*) Tracing cloth.

Other equipment may be needed according to the nature of the work.

Lettering. — There is much truth in the statement that good letterers are born and not made. Yet it is surprising how much one can improve in lettering by giving attention to a few guiding principles.

For most diagrams it is best to adopt a very simple style of letter. Shaded letters look well on maps, but are out of place on line diagrams. The two styles shown in Fig. 26 are suitable for ordinary work. The choice of a vertical letter or a sloping letter is largely a matter of taste. Most people are more successful with sloping letters. They can be made a little more rapidly, but they are perhaps a little more informal than vertical letters.

It is important that letters appear to be uniform in height and slope. It is well to use guides both as to height and slope. Letters should also appear to be spaced uniformly. The curves of such letters as C, G, O and S should extend slightly above and below the horizontal guide lines. Adjacent straight-line letters such as N, I, U, M, etc., should be spaced a little farther apart than curved letters. Attention should be given to the manner of making the strokes as shown in the plate.

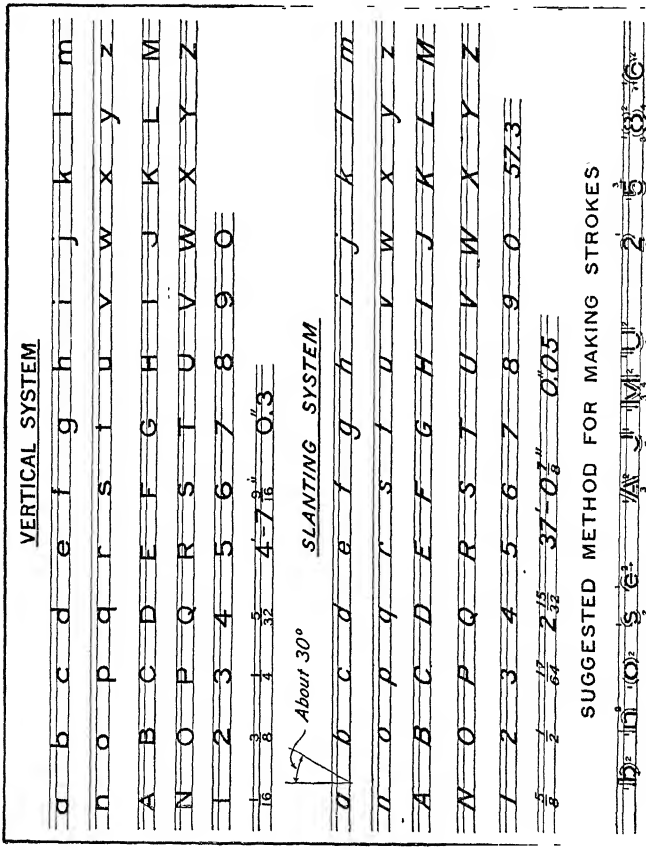


FIG. 26. — Lettering.

The student should consult a book on lettering such, for example, as that of Reinhardt. A "lettering triangle," which can be obtained from dealers in drawing materials, is also useful as a guide to slopes and spaces of letters.

If the title is inset it should be carefully placed. In general the lower right-hand corner is the best place for it, but often its location is governed by available space. The sizes of letters used should follow the important words. Each line should be centered. Write each line on a scrap of paper: count the letters in it: find the middle letter: put that down first and then letter backwards and forwards. Capitals may be used for the principal lines of a title. In a general sort of way try to arrange the lines so that a line circumscribing the title will be approximately an ellipse.

Label each scale, except that it is unnecessary to do so in the case of months and years. Do not use abbreviations. If there is more than one plotted line label each one. Be free in the use of explanatory notes. A diagram should tell its own story. In doing this use letters of readable size. It is a good rule never to make a let er or a figure less than $\frac{1}{8}$ inch in height.

Somewhere on the sheet, but outside of the diagram itself, should be placed the initials of the person who made the diagram and the date. This is valuable for identification, but it need not be published.

Suggestions of committee on standards. — The committee on Standards for Graphic Representation referred to on page 59 has offered the following suggestions which in the main agree with what has just been said.

1. The general arrangement of a diagram should proceed from left to right, and from bottom to top.
2. Where possible, quantities should be represented by linear magnitudes, rather than by areas or volumes
3. Whenever practicable, the zero line of the vertical scale should appear on the diagram.
4. If the zero line of the vertical scale does not normally appear, this should be indicated by an irregular horizontal break in the diagram.
5. The zero lines of the scales should be sharply emphasized from the other coördinate lines by making them heavier.

6. Where percentages are shown, both the zero line and the 100 per cent line should be emphasized.
7. When a scale refers to dates and the period represented is not a complete unit, the first and last ordinates should not be emphasized, since they do not represent the beginning or the end of time.
8. When logarithmic coördinates are used, the limiting lines of the diagram should be at some power of ten.
9. It is advisable not to show any more coördinate lines than necessary to guide the eye in reading the diagram.
10. The plotted lines of a diagram should be sharply distinguished from each other and from the ruling.
11. If curves represent a series of observations, it is advisable, whenever possible, to indicate clearly on the diagram all the points which represent separate observations.
12. The figures for the scales should be placed at the left and at the bottom along the respective axes.
13. It is often desirable to include in the diagram the numerical data or formulae represented.
14. If the numerical data are not included in the diagram, it is often desirable to give them in a table accompanying the diagram.
15. Letters and figures should be placed so as to be read easily from the base or the right-hand edge as the bottom.
16. The title should be as clear and complete as possible, sub-titles or descriptions being added if necessary to insure clearness.

Wall charts. — Wall charts are much used nowadays in the display of vital statistics. It is not difficult to prepare these, but certain general principles should be kept in mind. They should be simple and clear, of ample size and plainly lettered. If intended to be seen from a distance the letters should be large and the lines heavy. As lettering forms an important part of a wall diagram it is well to know that gummed letters of all sizes can be purchased. Examples of these letters are shown in Fig. 27.

The use of color in diagrams. — Colored lines should be used sparingly if the diagrams are to be published. A sheet must go through the press once for each color and this adds to the cost. The most effective use of color is where a single colored line is made to stand out in contrast to other black lines, and for this purpose red is the best. Color on plotted lines may be avoided by using black lines made in different ways. The following are easily distinguishable:

1. Heavy full line
2. Light full line
3. Heavy broken line
4. Light broken line
5. Dotted line
6. Dot-dash line

For wall charts or posters intended to be viewed from a distance, colors are justifiable.

The cross-section lines on the ruled paper ordinarily sold are colored green or brown or light red. Very bright colors used for this purpose are exceedingly trying on the eyes. It is desirable however to have a color which can be photographed and also blue-printed. For blue-prints vermillion red is better than carmine. Green photographs more lightly than red.

Component part diagrams. — In order to show the component parts of a total number we may subdivide a line or a long rectangle and label each part, or we may subdivide an area, as a square or a circle, indicating differences by colors, shades or patterns as in cartography. A circle properly subdivided is an excellent type of diagram to show percentages. Here the sectors plainly show the desired

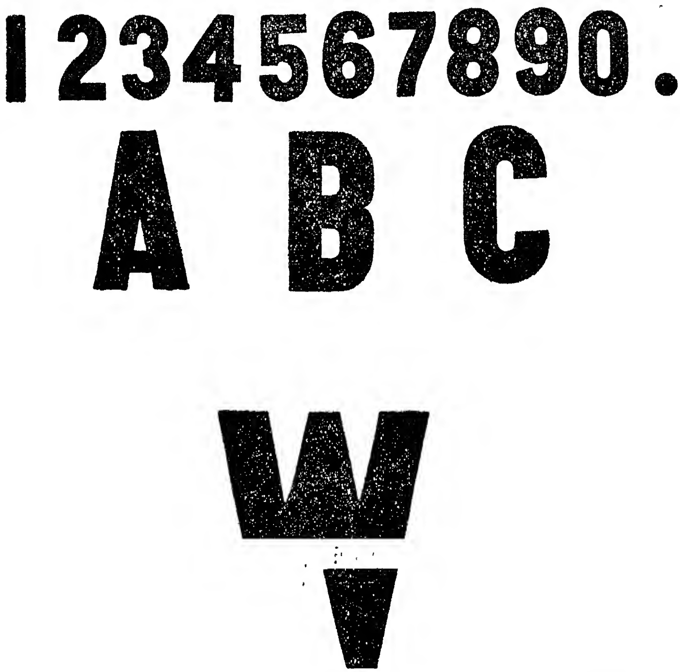


FIG. 27.—Examples of Gummed Letters, Useful for Wall Diagrams.

differences. This sort of a diagram is not to be confused with plotting by polar coördinates. (See Fig. 28.)

Statistical maps. — The object of statistical maps is to display classes and groups of statistics for different areas. It will be remembered that statistical *classes* involve differences which cannot be expressed in figures, but that statistical *groups* contain facts similar in kind but which differ from each other numerically. This difference should be kept in mind in preparing statistical maps.

The statistical data are shown on maps by different colors, by different patterns of lines and dots or by sur-

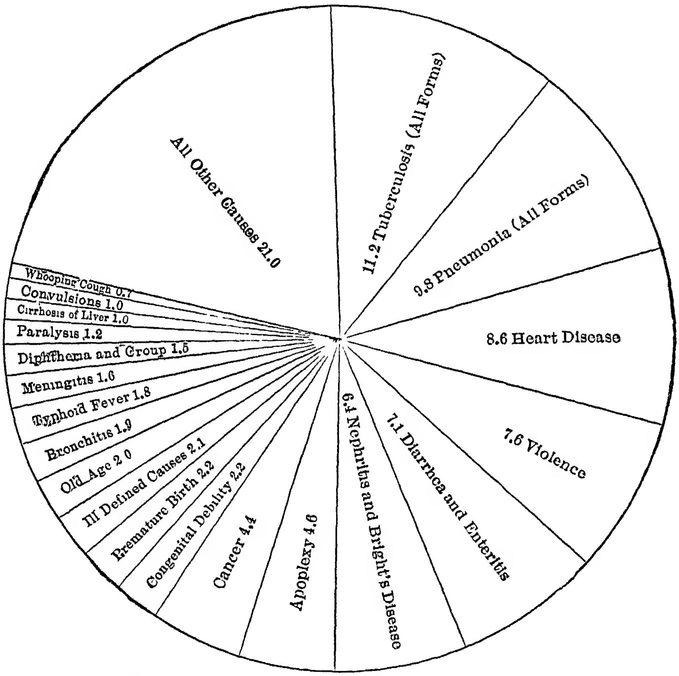


Fig. 28. — Proportion of Deaths from Each Specified Cause in the U. S. Registration Area: 1907.

face shadings. In the display of data arranged in groups, that is, in accordance with magnitude, it is well to indicate the differences by variations in shade from light to dark. In the display of data arranged by classes it is well to use different patterns or colors. Different shades may be obtained by successive washes of color applied with a brush, or by the use of cross-hatching in which the proportion of surface covered with ink regularly increases. The so-called "Ben Day" system of indicating shades by the use of special devices is well known to printers and engravers.[1]

Sometimes the figures themselves are placed on the maps. If this is done care should be taken to make sure that the boundaries of the areas to which the figures apply are properly defined.

Blue prints and other prints. — It is often desirable to obtain several copies of the diagrams made, and the quickest and cheapest method is that of making blue prints. The process is the same as that of making photographic prints from a negative. Blue-print paper can be purchased; in fact, it can be easily made. A large photographic printing frame is required. The diagram is placed in the frame over the blue-print paper and exposed to the sunlight for a few minutes, after which the paper is washed in water and dried. It is necessary, of course, to have the paper on which the diagram is made fairly thin and transparent. Paper should be selected with blue-printing in mind. The transparency of paper can be greatly increased by oiling it on the back after the diagram is made. A liquid sold under the name of "transparantine" is satisfactory. The best blue prints of diagrams are obtained by the use of tracing cloth. This has many advantages. It is easy to ink on and erasures may be made. The lines are sharp and photograph well. The cloth does not tear. The cloth is oiled on one side. The drawing should be done on the other. A little powdered chalk should be dusted on and rubbed off before using ink. Pencil lines may be used as guide lines and erased before blue-printing.

In the ordinary blue print the lines are white and the background blue. Additional white lines can be drawn on

[1] See Brinton's Graphic Methods. pp. 216, 233.

the blue by using a weak solution of caustic soda in a pen as ink.

It is possible to obtain prints in which blue or brown lines appear on a white ground. This requires the making of a negative, from which subsequent prints are made.

Reproduction of diagrams. — The common method of reproducing diagrams for publication is to photograph them and print from a zinc plate. This is the cheapest and most available method. It is necessary that the original drawing be well made, with lines of the right weight and the letters of the right size. All imperfections are of course reproduced. Usually the drawing should be made at least fifty per cent larger than the published plate, that is, the size is reduced one-third. To have diagrams made by a draughtsman costs something, but, if the photographic process is to be used, it is worth while. The draughtsman should know what the size of the published plate is to be.

Those not skilled in making diagrams ought to know that there is another process of reproduction which does not require a carefully drawn original, namely, that of wax engraving. In this process the engraver does the work of the draughtsman. A copper plate is used. The lettering in this process can be put in with type. This results in perfect legibility, which is often not the case with photographic work. Reproduction by the wax process costs almost twice that by the photographic process, but if to the latter is added the time and expense of preparing a perfect original the wax process costs no more. Most of the plates in this book were made by the wax process by the L. L. Poates Company of New York. Unfortunately there are not many wax engravers in this country.

Equation of a curve. — Having plotted certain data on rectangular coördinate paper, that is, using a horizontal and a vertical scale, and finding that the points fall on a straight line or on a regular curve, it is sometimes desirable to find the equation of the straight line or curve. This is not difficult, but it requires the use of mathematical principles not considered in this book. The reader is referred to such books as Saxelby's "A course in Practical Mathematics"[1] or Peddles' "Construction of Graphical Charts."[2]

EXERCISES AND QUESTIONS

1. Describe Ripley's method of preparing statistical maps with different shadings. [Pub. Am. Sta. Asso., Sept. 1899, pp. 319–322.]

2. Construct a graph of the birth-rates and death-rates of Sweden from 1749 to 1900. (See p. 259.)

3. Construct a graph of the natural rate of increase of the population of Sweden from 1749 to 1900.

4. Show by suitable diagrams the data in Tables 109, 115 and 120.

5. Find diagrams in this book which do not conform to the principles described in Chapter III.

6. Construct a "devil's checker-board," as follows:

a. Take a piece of cardboard or heavy drawing paper and rule in black ink a rectangle $8\frac{1}{2}''$ wide and $11''$ high. Rule also a horizontal line $1''$ below the top, and a vertical line $1''$ from left-hand edge, in order to leave suitable margins at top and left.

b. Subdivide the $7\frac{1}{2}''$ on the horizontal line into 15 half-inch spaces and rule vertical lines. Subdivide the $10''$ on the vertical line into 40 quarter-inch spaces and rule horizontal lines.

c. Draw in red inclined lines sloping downward to the left, being $\frac{1}{2}''$ apart in a horizontal line and $1\frac{1}{4}''$ apart in a vertical direction.

If the work is done accurately certain of these diagonals will intersect corners of the small rectangles; if the work is not accurate the name of the problem is justified. These guide lines will be found convenient in the construction of tables. The sloping lines will serve as guides for sloping letters.

7. Construct a colored wall chart showing the death-rates from several diseases for some city, using the one-scale type of diagram. Assume the chart is to be read from a distance of twenty feet.

[1] Pub. by Longmans, Green & Co., 1908.

[2] Pub. by McGraw-Hill Book Co., 1910.

8. Describe the method of construction and the varied uses of ratio cross-section paper. (Quar. Pub. Am. Sta. Asso. June, 1917, p. 577.)

9. Plot the population of some city (assigned by the instructor) using ordinary cross-section paper and ratio paper.

10. Construct a colored component-part diagram (subdivided circle), showing the composition of the population of some city or state (data assigned by the instructor).

CHAPTER IV

ENUMERATION AND REGISTRATION

All civilized nations at regular periods enumerate their populations, that is, take a census. There are various governmental reasons for doing this, two important ones being the adjustment of representation in legislative bodies and the levying of taxes. There are also business, social and sanitary uses to which the figures are put. In considering a census several questions immediately arise; when was it made, what area was included, how were the data obtained, what were the results and where may they be found?

The United States census. — The first general census of the United States was made in 1790, the first year divisible by ten after the founding of the new republic, and a census has been taken every ten years since that date, the census of 1910 being the thirteenth.

The first twelve censuses were made by special commissions created for the purpose and which went out of existence as soon as the task had been accomplished. A permanent Bureau of the Census was created in 1902. At first it was under the Department of the Interior, but in 1903 was transferred to the Department of Commerce and Labor. It is now in the Department of Commerce.[1] Its head is known as the Director of the Bureau of the Census. Besides taking the general census of the country every ten years this bureau is charged with the collection of sta-

[1] Census Act of March 3, 1919.

tistics of many kinds relating to the people, vital statistics, financial statistics, municipal statistics, statistics of agriculture, fishing, manufacture, transportation, mining, and others.

The census data prior to 1910 were published as a series of special volumes by the commission having the work in charge. Many of the older volumes are out of print, but may be found in large libraries. In 1900 there were three volumes on population and two volumes on vital statistics obtainable by purchase from the U. S. Publication Office at Washington. Bulletins of the census may be obtained from the "Director of the Census, Washington, D. C." Lists of available reports and bulletins may be obtained without charge by writing to the director.

In 1910 the report of population comprised four large volumes. The first contained the general data for the country, classified and grouped in many ways; the second and third gave the population subdivided by civil divisions; the fourth, occupations. For some time it has been customary to include in each census report the populations for the two censuses preceding. This is for comparison and to enable estimates of population to be made. Thus, in the thirteenth census will be found the populations for 1910, 1900 and 1890.

A table often consulted was that on page 430 of Vol. I, Part I, of the U. S. Census of 1900, which gave the populations of all cities which were larger than 25,000 in 1900, for every census since 1790. In the 1910 census these figures are given in the second and third volumes mentioned under the head of each state. See also pages 80–97 of the first volume.

The results of the Fourteenth Census are now being published as a series of volumes. Vol. I gives the number and distribution of the inhabitants for the years 1900, 1910 and 1920.

These census reports should be in every public library, and in the library of every city government, as they contain a vast amount of important information relative to the growth and condition of our country. Every student of demography should become thoroughly familiar with the U. S. Census reports.

The census date. — For most purposes it is sufficiently accurate to say that the census was taken in a certain year, but for the more exact computations a definite day must be named. The population of the country is constantly changing, even from hour to hour. If we wish to use the figure which best represents the population for any year we should naturally choose the population as it was at the middle of the year, namely July 1st. But it is not practicable to enumerate all of the people on a single day, and July 1st is not the best time to make the enumeration because being in the vacation season many people are likely to be away from home. For practical reasons another day is chosen as the official day for taking the census.

In 1920 this day was Jan. 1. It took thirty days to make the enumeration, but the data were adjusted to this day so that the statistics are stated "as of Jan. 1st." But it should be noted that in 1900, in 1890, and back to 1830 the official date was June 1. In 1910 it was April 15th. Hence between the census of 1900 and 1910 the interval was not 10 years, but ten years less $1\frac{1}{2}$ months (April 15 to June 1) or $1\frac{1}{4}$ per cent less than ten years. Between 1910 and 1920 the interval was ten years less $3\frac{1}{2}$ months (Jan. 1 to Apr. 15), or nearly 3 per cent less than ten years. In some computations this introduces an appreciable error and a correction must be made. From 1820 back to 1790 the day of the census was the first Monday in August.

In Great Britain, including Canada and Australia, the national census is taken every ten years, but one year later than in the United States, that is, in 1911 and 1921. This has been so since 1801. The time of the census is " at midnight before the first Monday in April."

It is quite possible to adjust the population of the census year, so as to find what it was on July 1st of that year, and this has been done by the U. S. Census Bureau and the figures used for the computation of mortality statistics for that year. The method used is described in the next chapter.

Civil divisions. — The population of the United States is given in the census reports by minor civil divisions. The total population of the nation is subdivided into continental and " outlying possessions," the latter including Alaska, the Philippine Islands, the Hawaiian Islands, Porto Rico, and several smaller possessions as well as persons in naval and military service stationed abroad. The Fourteenth Census covered only the United States proper. The continental population is subdivided into states; the states into counties; the counties into cities, boroughs or towns; the cities into wards; the boroughs and towns into villages and rural regions. These civil divisions differ somewhat in different parts of the country.

In comparing the figures for different decades it must be remembered that the boundaries of the civil divisions are subject to change. State boundaries are quite permanent, but cities frequently increase by annexation of suburbs, and ward lines change still more frequently according to political exigencies. In most cases changes of boundaries are indicated in the census reports by explanatory notes.

In sending to the Director of the Census for reports of populations by states or for the whole country, the request should be made for that report which gives the facts by " minor civil divisions."

The enumeration schedule of 1920. — In taking the census of 1920 the country was divided into numerous supervisor's districts each under the charge of a supervisor appointed by the President. About 70,000 enumerators were selected by the supervisors, or one for about every 1000 persons. The enumerators were required to visit each dwelling and collect the various statistics included in the schedule.

The enumerators began their work throughout the country on Jan. 2, 1920. The law provided that this should be completed within two weeks in cities of 2500 or more inhabitants, and within 30 days elsewhere.

The schedule of facts to be collected was printed on large sheets of paper, on which were 50 horizontal lines, numbered from 1 to 50. The facts for each person occupied one line.[1]

The schedule corresponded closely to those used in the censuses from 1850 to 1880 and 1910. The schedule used in 1890 was somewhat different, a separate schedule sheet being employed for each family.[2]

For purposes of compilation the facts for each person were transferred to a separate punched card. These cards were then sorted by machine.

The data collected by the enumerators for each person were as follows:

At the top of each sheet were given the state, county, township or other division of county, name of incorporated place, name of institution (if any), ward of city, number of supervisor's district, number of enumerator's district, name of enumerator and date of enumeration.

[1] U. S. Census, 1920, Vol. I, p. 694.

[2] U. S. Census, 1890, Population, Part I, CCIV.

Schedule

Place of Abode.

1. Street, Avenue, Road, etc.
2. House number or farm, etc. (See instructions.)
3. Number of dwelling house in order of visitation.
4. Number of family in order of visitation.
5. *Name* of each person whose *place of abode* on January 1, 1920, was in this family. (Enter surname first, then the given name and middle initial, if any. Include every person living on January 1, 1920. Omit children born since January 1, 1920.)
6. *Relation.* Relationship of this person to the head of the family.

Tenure.

7. Home owned or rented.
8. If owned, free or mortgaged.

Personal Description.

9. Sex.
10. Color or race.
11. Age at last birthday.
12. Single, married, widowed, or divorced.

Citizenship.

13. Year of immigration to the United States.
14. Naturalized or alien.
15. If naturalized, year of naturalization.

Education.

16. Attended school any time since Sept 1, 1919.
17. Whether able to read.
18. Whether able to write.

Nativity and Mother Tongue.

Place of birth of each person and parents of each person enumerated. If born in the United States, give the state or territory. If of foreign birth, give the place of birth and, in addition, the mother tongue. (See instructions.)

Person.

19. Place of birth
20. Mother tongue.

Father.

21. Place of birth
22. Mother tongue.

Mother.

23. Place of birth.
24. Mother tongue.
25. *Whether Able to Speak English.*

Occupation.

26. Trade, profession, or particular kind of work done, as *spinner, salesman, laborer, etc.*
27. Industry, business, or establishment in which at work, as *cotton mill, dry goods store, farm, etc.*
28. Employer, salary of wage-worker, or working on own account.
29. *Number of Farm Schedule.*

One has only to read over this list to see the importance of statistical definitions. What, for example, is meant by the "usual place of abode"? This is the place where he "lives" or "belongs" or "the place which is his home." As a rule it is *where he regularly sleeps.* And then what about those persons who have no place of abode, lodgers in one-night lodging houses, tramps, laborers in construction camps, etc.? Such persons have to be enumerated *where found.* It required a formidable book of instructions to make all these things plain to the enumerators.

Bowley's rules for enumeration. — The English statistician, Bowley, has laid down the following rules in regard to the collection of statistical data by the method of enumeration.

"In practice the enumerator is usually furnished with blanks to be filled out and with questions to be answered. These questions should be:

1. Comparatively few in number.
2. Require an answer of a number or of a "yes" or "no."
3. Simple enough to be readily understood.
4. Such as will be answered without bias.
5. Not unnecessarily inquisitorial.
6. As far as possible corroboratory.
7. Such as directly and unmistakably cover the point of information desired.

These rules apply equally well to the collection of data by registration."

Credibility of census returns. — It is not to be expected that the census figures are strictly accurate. Errors are bound to be made by the enumerators; some persons are sure to be omitted from the count, especially those traveling; some may be counted twice; and in rare instances the lists have been thought to be padded. Taken as a whole, however, the results may be considered as reliable, and it should be noted that the published data of the U. S. Census are accepted as evidence which may be introduced without proof in courts of record. Unless there is good reason for doing otherwise they should be used instead of local estimates as the basis of computing vital rates. As a rule also they should be used in place of state censuses, but there are some exceptions to this.

Collection of facts by registration and notification. — If it is difficult to secure accurate statistics of population obtained by enumerators hired for the purpose and properly instructed, how much greater the difficulty to obtain complete and accurate statistics by the method of registration, when the returns are made by large numbers of physicians, undertakers, clergymen, nurses and laymen not properly instructed, not interested in the proceedings and not always understanding the law, with inadequate laws, and with governments too easy-going to insist on the enforcement of such laws as exist! And yet most of the vital statistics of the country are collected in this way. Worst of all, the people at large do not appreciate the personal importance of having the most important events in their lives, — birth, marriage and death, — made matters of public record.

By registration is meant the reporting of certain events and associated facts to a governmental authority and the official filing or recording of such facts. The reports are made in accordance with prescribed rules and usually on a blank designed for the purposes.

Most nations in one way or another have endeavored to preserve their history by keeping these personal records. In England the registration of baptisms, marriages and deaths dates back to 1538 when Thomas Cromwell, Vicar General under Henry VIII, issued injunctions to all parishes in England and Wales requiring the clergy to enter every Sunday, in a book kept for the purpose, a record of all baptisms, marriages and burials of the preceding week. In 1653 this work was assigned to "parish registers." It was not until 1837 that registration of births, marriages and deaths became a civil function. In 1870 it was made compulsory. In parts of Canada the registration of births and deaths is still on a parish instead of a civil basis.

In the early American colonies the practice of recording births, marriages and deaths was instituted. In New England the town clerk figured largely. In Massachusetts a fairly definite law was passed in 1692, according to which the town clerk was required to keep such records, and there were fees to be paid him for so doing, and penalties for those persons who withheld the desired information. This act was altered in 1795. In 1842 a registration act was passed in Massachusetts which made the Secretary of the Commonwealth the custodian of these records. This act, together with an amplifying act in 1844, forms the basis of registration in Massachusetts to this day. It was brought about largely through the activities of Lemuel Shattuck.[1]

The story of the registration of vital statistics is too long to be told here. Many physicians, like Dr. Edward Jarvis, of Boston, and many committees of such organizations as the American Medical Association and the American Public Health Associations have played prominent parts in the

[1] State Sanitation, by George C. Whipple, Vol. I, p. 56.

movement. At the present time the United States Bureau of the Census is taking the lead in urging necessary reforms in the registration of vital statistics.

The laws relating to the registration of vital statistics are not the same in all states. In Massachusetts a State Registrar in the office of the Secretary of the Commonwealth has charge of the matter, but in many states the State Board (or Department) of Health has charge. In order to bring about uniformity a model law was drafted and endorsed by a number of national organizations and this has been adopted by a number of states. Some of the older states, however, still maintain their old arrangement. This model law should be carefully studied. It may be found in the Appendix.

Registration of births. — It is important that the birth of each and every child born be duly registered.

The information desired for the legal, social and sanitary purposes, according to the United States standard certificate approved by the Bureau of the Census, and in use since 1906, is as follows:

1. Place of birth, including State, county, township or town, village, or city. If in a city, the ward, street and house number; if in a hospital or other institution, the name of the same to be given, instead of the street and house number.
2. Full name of child. If the child dies without a name, before the certificate is filed, enter the words "Died unnamed." If the living child has not yet been named at the date of filing certificate of birth, the space for "Full name of child" is to be left blank, to be filled out subsequently by a supplemental report, as hereinafter provided.
3. Sex of child.
4. Whether a twin, triplet, or other plural birth. A separate certificate shall be required for each child in case of plural births.
5. For plural births, number of each child in order of birth.
6. Whether legitimate or illegitimate. (This question may be omitted if desired, or provision may be made so that the identity of parents will not be disclosed.)

7. Date of birth, including the year, month and day.
8. Full name of father.
9. Residence of father.
10. Color or race of father.
11. Age of father at last birthday, in years.
12. Birthplace of father; at least State or foreign country, if known.
13. Occupation of father. The occupation to be reported if engaged in any remunerative employment, with the statement of (*a*) trade, profession, or particular kind of work; (*b*) general nature of industry, business, or establishment in which employed (or employer).
14. Maiden name of mother.
15. Residence of mother.
16. Color or race of mother.
17. Age of mother at last birthday, in years.
18. Birthplace of mother, at least State or foreign country, if known.
19. Occupation of mother. The occupation to be reported if engaged in any remunerative employment, with the statement of (*a*) trade, profession, or particular kind of work; (*b*) general nature of industry, business, or establishment in which employed (or employer).
20. Number of children born to this mother, including present birth subdivided as follows: — (*a*) born alive and now living. (*b*) born alive and now dead. (*c*) still-born
21. Number of children of this mother living.

The duty of making out this certificate rests upon the attending physician, mid-wife or person acting as such, or in their absence upon the father or mother of the child, the householder or owner of the premises where the birth occurred or the manager or superintendent of the institution, public or private, where the birth occurred, each in the order named. This certificate must be filed with the local registrar within ten days after the date of the birth. A supplemental blank is provided in case the child has not been named when the first report is submitted. The local registrar, or a sub-registrar, must examine this certificate as to completeness and probable accuracy, secure corrections if necessary, keep a record of the birth certificates received, numbered serially as received, and once a month transmit the original certificates to the State Registrar, for permanent preservation. Small fees to local registrars for the recording of births are provided and likewise penalties for failure. Provision is made for giving certified copies of the birth records to persons entitled to receive them.

The period of time within which a birth must be recorded may with advantage be less than the ten days above mentioned, especially in cities; in fact it is best that the birth be reported within twenty-four hours. If, as should be the case, the local registrar is connected or closely associated with the local board of health, the prompt information that a birth has occurred enables the health officer to send a visiting nurse to offer advice and assistance in caring for the child. Infant mortality cannot be greatly reduced in cities unless this prompt report is made.

Advantages to individuals of having births publicly recorded. — Legal evidence is thus made available as to: —

Place of Birth, useful to prove citizenship (necessary for pass-ports), to prove residence, to acquire a legal "settlement."

Time of Birth, useful to prove age, to obtain admission to school, to establish right to go to seek employment under the child labor law, to prove liability for military service, to prove the age at which the marriage contract may be entered into, to establish right to vote, or hold public office, to establish the right to hold, buy or sell real estate, to obtain pensions.

Parentage, to establish identity, to prove nationality, to prove legitimacy, to inherit property, to obtain settlement of insurance, to establish citizenship.

What are some of the evidences of incomplete birth registration? — Dr. Louis I. Dublin has suggested three simple tests. *First.* The number of births registered in a calendar year should be greater than the number of living children under one year of age. *Second.* The birth-rate does not usually vary greatly from year to year. Wide and erratic variations indicate probable deficiencies in reporting. *Third.* Birth-rates less than 20 per thousand (or less than 25 per thousand in cities which have large foreign populations) are uncommon where registration is complete.

Enforcement of the registration law. — The persons most concerned in the enforcement of the birth registration law are (1) the state registrar, who should preferably be associated with the state department of health; (2) the local registrar, who should preferably be associated with the local board of health; (3) the physician, whose duty it is to make the report; and (4) the parents of the child and the child himself or herself.

In order that better registration be obtained parents and physicians should be made to understand the benefits which result to individuals and to the community. Facilities in the form of suitable blanks, etc., should be provided, so as not to make the matter of reporting a burden to busy physicians. It might well be that a simple post-card notification, stating that a birth occurred at such and such a place, sent on the day of birth, with a complete certificate filed at a later date would help to solve the problem. No fee should be given to a physician who does not report within the statutory time limit. What is most needed however is a rigid enforcement of the penalty clause. A local registrar once gave the author as the reason for not imposing fines on physicians for failure to report, — "I am too good natured." This spirit is fatal to good government.

Registrars are not without opportunity to obtain evidence of neglect. In the case of reported infant deaths the local registrar should ascertain if the child's birth had been recorded. Church records of baptisms may be compared with birth returns. The checks are not as complete as in the case of death returns, but an ingenious local registrar will have little difficulty in getting good returns if he takes his task seriously.

In Cambridge, Mass., the birth records were at one time so incomplete that annually a house to house canvass had to be made to ascertain the births for the year. This was a disgraceful admission of incompetence on the part of the local registrar and of the negligence of all concerned. No fines were imposed and some of the payments of fees were, with a proper interpretation of the law, of questionable legality. Unfortunately Cambridge has not been alone in this, but is typical of hundreds of other cities.

Registration of deaths. — The facts desired in connection with deaths are as follows, according to the United States Standard Certificate.

1. Place of death, including State, county, township, village, or city. If in a city, the ward, street, and house number; if in a hospital or other institution, the name of the same to be given instead of the street and house number. If in an industrial camp, the name of the camp to be given.

2. Full name of decedent. If an unnamed child, the surname preceded by "Unnamed."

2a. Residence at usual place of abode (ward, street and number), and length of residence in city or town where death occurred in years and months. Also how long in United States if of foreign birth.

3. Sex.

4. Color or race, as white, black, mulatto (or other negro descent), Indian, Chinese, Japanese, or other.

5. Conjugal condition, as single, married, widowed, or divorced.

5a. If married, widowed, or divorced. Name of husband or wife.

6. Date of birth, including the year, month, and day.

7. Age, in years, months, and days If less than one day, the hours or minutes.

8. Occupation. The occupation to be reported of any person, male or female, who had any remunerative employment, with the statement

of (*a*) trade, profession or particular kind of work; (*b*) general nature of industry, business, or establishment in which employed (or employer); (*c*) name of employer.

9. Birthplace; at least State or foreign country, if known.
10. Name of father.
11. Birthplace of father; at least State or foreign country, if known.
12. Maiden name of mother.
13. Birthplace of mother; at least State or foreign country, if known.
14. Signature and address of informant
15. Official signature of registrar, with the date when certificate was filed, and registered number.
16. Date of death, year, month, and day.
17. Certification as to medical attendance on decedent, fact and time of death, time last seen alive, and the cause of death, with contributory (secondary) cause of complication, if any, and duration of each, and whether attributed to dangerous or insanitary conditions of employment; signature and address of physician or official making the medical certificate.
18. Where was the disease contracted if not at place of birth? Did an operation precede death? If so give date. Was there an autopsy? What test confirmed diagnosis?
19 Place of burial or removal; date of burial.
20. Signature and address of undertaker or person acting as such.

The first thirteen items are chiefly personal and these facts may be signed by any competent person acquainted with the facts. Items 16 and 17 comprise the medical certificate, which must be made out by the physician, if any, last in attendance. In the absence of medical attendance the undertaker must notify the local registrar who may not issue a burial permit until the case is referred to the local health officer for investigation and certification. In case there is suspicion of neglect or unlawful act the coroner, medical examiner, or other proper officer must conduct an investigation. There are various provisos, differing in different states, which should be known by every physician and nurse and, of course, by every health officer. Finally items 19 and 20 must be signed by the undertaker.

The certificate of death thus made out and duly signed must be filed by the undertaker with the local registrar (in some states the local board of health), and a burial permit or removal permit obtained prior to the disposition of the body. This permit must be delivered before burial to the person in charge of the place of burial. If the body is transported the undertaker must attach a removal permit to the box containing the corpse in order that it may reach the person in charge of the place of burial.

Thus the undertaker is primarily responsible for filing the certificate with the local registrar (or local board of health), but the physician is responsible for making out certain very essential parts of the certificate.

Records of death certificates and burial permits are of course kept by the local registrar (or local board of health). Thus there is a check on the death certificate, and partly for this reason the registration of deaths is more complete than the registration of births. It is easier to come into the world without public notice than it is to leave it.

The data regarding the deaths are transmitted by the local registrar to the state registrar.

Uses of death registration. — The uses of death registration are legal, economic, and social. It assists in the prevention and detection of crime. It is invaluable in the settlement of life insurance and property inheritance cases. It furnishes the basis of genealogical studies. The statistics based upon these records have been a powerful weapon in studying disease, and therefore in improving the health of the race and lengthening human life. The records may be of great local value in the study and suppression of epidemics and outbreaks of communicable diseases.

Marriage registration. — There is no uniform or "model" marriage law in the United States; state laws differ from each other. The custom is that persons desiring to marry must first obtain a civil license from a designated local official and present it to the authorized person who performs the ceremony. The person officiating is required to register the marriage. The persons responsible for marriage registration are therefore the clergymen and the justices of the peace.

The facts required in the registration of marriages are commonly as follows:

1. Date of the marriage.
2. Place of the marriage.
3. Names of the persons married.
4. Their places of birth.
5. Their residences.
6. Their ages.
7. Their color.
8. The number of the marriage (as the first or second).
9. If previously married, whether widowed or divorced.
10. Their occupations.
11. The names of their parents.
12. The maiden names of their mothers.
13. The date of the record.
14. The signature of the officiating person.
15. His residence and official station.

Unfortunately the registration of marriages suffers from neglect of the persons officiating. It is difficult also to avoid duplication. Bride and groom living in different towns require each a license. Statistically there is danger that the marriage may be counted twice.

Morbidity registration. — The compulsory registration of cases of disease dangerous to the public health is comparatively modern. It is true that many years ago such dreaded diseases as smallpox had to be reported, but it is since the organization of modern health departments and the general understanding of the manner in which communicable diseases are spread that compulsory notification has become widespread. In 1874 the State Board of Health of Massachusetts took the lead by arranging a plan for the weekly voluntary notification of *prevalent* diseases. Over a hundred physicians agreed to make this report. Ten years later, in 1884, the state passed a law requiring householders and physicians to report immediately to the selectmen or board of health of the town all cases of smallpox, diphtheria, scarlet fever, or any other disease dangerous to the public health. Other states followed suit.

The requirement of notification of diseases is an act of police power and authority for it resides in the state governments. In Massachusetts legislative authority has been delegated to the State Board of Health (now the State Department of Public Health) to determine what diseases are dangerous to the public health, and such diseases must be reported according to prescribed rules. Power is oftened delegated to local communities to supplement the state requirements for local reports. At the present time the regulations in the several states differ greatly from each other.

In 1913 a model law for morbidity reports was adopted by a conference of state and territorial health authorities and the U. S. Public Health service. According to this law the state boards (or departments) of health are required to provide machinery for keeping informed as to current diseases dangerous to the public health; physicians are required to report cases of such diseases immediately to the local health authorities having jurisdiction; teachers in schools must do the same; these records must be promptly sent to the state authorities. There are various provisos and provisions for keeping records, and for penalties. The data required are the following:

1. The date when the report is made.
2. The name of the disease or suspected disease.
3. Patient's name, age, sex, color, and address. (This is largely for purposes of identification and location.)
4. Patient's occupation. (This serves to show both the possible origin of the disease and the probability that others have been or may be exposed.)
5. School attended by or place of employment of patient. (Serves same purpose as the preceding.)
6. Number of persons in the household, number of adults and number of children. (To indicate the nature of the household and the probable danger of the spread of the disease.)
7. The physician's opinion of the probable source of infection or origin of the disease. (This gives important information and frequently reveals unreported cases. It is of particular value in occupational diseases.)
8. If the disease is smallpox, the type (whether the mild or virulent strain) and the number of times the patient has been successfully vaccinated, and the approximate dates (This gives the vaccination status and history.)
9. If the disease is typhoid fever, scarlet fever, diphtheria, or septic sore throat, whether the patient had been or whether any member of the household is engaged in the production or handling of milk. (These diseases being frequently spread through milk, this information is important to indicate measures to prevent further spread.)
10. Address and signature of the physician making the report.

Notifiable diseases. — A list of notifiable diseases was included in the model law of 1913. Obviously this cannot be a permanent one. It is being continually revised chiefly by addition. In many states influenza was added to the list during the epidemic of 1918. Under present conditions the lists vary in different states but the following diseases are commonly included.

GROUP I. — INFECTIOUS DISEASES.

Actinomycosis.
Anterior poliomyelitis.
Anthrax.
Chicken-pox.
Cholera. Asiatic (also cholera nostras when Asiatic cholera is present or its importation threatened).

Continued fever lasting seven days.
Dengue.
Diphtheria.
Dog-bite (requiring anti-rabic treatment).
Dysentery:
(a) Amebic.
(b) Bacillary.
Encephalitis lethargica.
Favus.
German measles.
Glanders.
Hookworm disease.
Influenza.
Leprosy.
Malaria.
Measles.
Meningitis:
(a) Epidemic cerebrospinal.
(b) Tuberculous.
Mumps.
Ophthalmia neonatorum (conjunctivitis of new-born infants).
Paratyphoid fever.
Pellagra.
Plague.
Pneumonia (lobar).
Poliomyelitis (acute infectious).
Rabies.
Rocky Mountain spotted, or tick, fever.
Scarlet fever.
Septic sore throat.
Smallpox.
Suppurative conjunctivitis.
Tetanus.
Trachoma.
Trichinosis
Tuberculosis (all forms, the organ or part affected in each case to be specified).
Typhoid fever.
Typhus fever.
Whooping cough.
Yellow fever.

GROUP II. — OCCUPATIONAL DISEASES AND INJURIES.

Arsenic poisoning.
Brass poisoning
Carbon monoxide poisoning.
Lead poisoning.
Mercury poisoning.
Natural gas poisoning.
Phosphorus poisoning.
Wood alcohol poisoning.
Naphtha poisoning.
Bisulphide of carbon poisoning.
Dinitrobenzine poisoning.
Caisson disease (compressed-air illness).
Any other disease or disability contracted as a result of the nature of the person's employment.

GROUP III. — VENEREAL DISEASES.

Gonococcus infection.
Syphilis.

GROUP IV. — DISEASES OF UNKNOWN ORIGIN.

Pellagra.
Cancer.

Incompleteness of morbidity statistics. — Complete accuracy in securing records of morbidity under any law is impossible. All of the cases existing are not seen by physicians, of the cases seen not all are recognized or correctly diagnosed, of those recognized not all are reported within the required time and some not at all. The chief error is that of incompleteness. Conservative physicians wait until sure of their diagnosis before reporting. A vast number of physicians are careless; a few deliberately shield their patients from possible inconvenience by withholding reports. More and more, however, physicians are coming to realize that in dealing with communicable diseases they have a public as well as a private duty. Death certificates give a partial check on morbidity reports. The ratios between statistics of sickness and death from reportable diseases furnishes a measure of the incompleteness of the reports. Trask has noted this difference between morbidity and mortality returns; death records are usually complete but the cause of death often incorrectly diagnosed, morbidity records are incomplete, but the diagnosis usually correct. This must be kept in mind in dealing with fatality ratios.

One of the hopeful signs looking towards a better registration is the action taken by the American Medical Association in June, 1919. The Section on Preventive Medicine and Public Health voted to recommend to the House of Delegates that it ask the constituent associations to consider the advisability of such amendments to their by-laws and to those of the A. M. A. as will eliminate from membership any physician who wilfully fails or refuses to comply with local or State laws for the prevention of disease, including especially the provisions in such laws requiring the reporting of cases of communicable diseases. (See P. H. Reports, June 27, 1919.)

Morbidity from non-reportable diseases. — It is much to be regretted that at the present time there is no adequate way of getting the facts in regard to sickness in the community due to diseases which are non-reportable. Sickness surveys are sometimes made, but they give only the facts at a given date, and are, moreover, very expensive to make. Hospital records help a little, the examinations made by the life insurance companies help a little, the recent examinations of men for the army have helped a good deal, but some day a more universal method must be devised.

Reporting venereal diseases. — For a number of years the matter of requiring physicians to report cases of venereal diseases as diseases dangerous to the public health has been under consideration by public health officials; in a few places it has been attempted. The present war has emphasized the need of such reports and these are now required in many states. For social reasons it is undesirable to have the names of the victims reported, yet under some conditions it is desirable and necessary in the control of disease. The following system was adopted by the Massachusetts State Department of Health in 1918 as a war measure.

1. Gonorrhœa and syphilis are declared diseases dangerous to the public health and shall be reported in the manner provided by these regulations promulgated under the authority of chapter 670, Acts of 1913.

2. Gonorrhœa and syphilis are to be reported (in the manner provided by these regulations) on and after Feb. 1, 1918.

3. At the time of the first visit or consultation the physician shall furnish to each person examined or treated by him a numbered circular of information and advice concerning the disease in question, furnished by the State Department of Health for that purpose.

4. The physician shall at the same time fill out the numbered report blank attached to the circular of advice, and forthwith mail the same to the State Department of Health. On this blank he shall report the following facts:

Name of the disease.
Age.
Sex.
Color.
Marital condition and occupation of the patient.
Previous duration of disease and degree of infectiousness.
The report shall not contain name or address of patient.

5. Whenever a person suffering from gonorrhœa or syphilis in an infective stage applies to a physician for advice or treatment, the physician shall ascertain from the person in question whether or not such person has previously consulted with or been treated by any other physician within the Commonwealth. If not, the physician shall give and explain to the patient the numbered circular of advice, as provided in the previous regulation.

If the patient has consulted with or been treated by another physician within the Commonwealth and has received the numbered circular of advice, the physician last consulted shall not report the case to the State Department of Health, but shall ask the patient to give him the name and address of the physician last previously treating said patient.

6. In case the person seeking treatment for gonorrhœa or syphilis gives the name and address of the physician last previously consulted, the physician then being consulted shall notify immediately by mail the physician last previously consulted of the patient's change of medical adviser.

7. Whenever any person suffering from gonorrhœa or syphilis in an infective stage shall fail to return to the physician treating such person for a period of six weeks later than the time last appointed by the physician for such consultation or treatment, and the physician also fails to receive a notification of change of medical advisers as provided in the previous section, the physician shall then notify the State Department of Health, giving name, ad-

dress of patient, name of the disease and serial number, date of report and name of physician originally reporting the case by said serial number, if known.

8. Upon receipt of a report giving name and address of a person suffering from gonorrhœa or syphilis in an infective stage, as provided in the previous section, the State Department of Health will report name and address of the person as a person suffering from a disease dangerous to the public health, and presumably not under proper medical advice and care sufficient to protect others from infection, to the board of health of the city or town of patient's residence or last known address. The State Department of Health shall not divulge the name of the physician making said report.

Sickness surveys. — A new method of securing data in regard to disease has been recently applied in an experimental way in a number of cities, namely that of making a house to house canvas to determine the number of persons ill at the time. The Metropolitan Life Insurance Company has been foremost in this undertaking under the direction of Dr. Lee K. Frankel and Dr. Louis I. Dublin. Spring and fall surveys have been made in several cities, the enumerator for the most part being the collecting agents of the insurance company.

The data sheet used included the age, sex, and occupation of each member of the family; and if sick the disease or cause of disability, its duration and extent, *i.e.*, whether confined to bed, and the kind of treatment, *i.e.*, by physician at home, hospital, or dispensary.

Surveys have been made for Rochester, N. Y., September, 1915; Trenton, N. J., October, 1915; North Carolina (sample districts throughout the state), April, 1916; Boston, Mass., July, 1916; Chelsea neighborhood of New York City, April, 1917; Pittsburg and other cities of Pennsylvania and West Virginia, March, 1917; Kansas City, Mo., April, 1917.

This method obviously has its advantages and disadvantages. Within its natural limitations the data secured ought to be of value and should furnish an excellent check on the results obtained by registration of communicable diseases.

Other methods of securing data. — It will not be possible to describe here all of the many ways in which data bearing on the health of a community may be secured, but mention should be made of the importance of hospital records, life insurance records, records of physical examinations made by the U. S. Army and Navy, records of physical examinations of school children. More and more the systematic physical examination of the people will be extended, until it becomes universal and compulsory. All of this will wonderfully increase our knowledge of vital statistics.

United States registration area for deaths. — The Bureau of the Census keeps records and publishes reports of the mortality of those parts of the United States where the statistics are sufficiently accurate to make it worth while to do so. A so-called registration area for deaths was established in 1880. This included those states and cities in which satisfactory registration laws were being effectively enforced and where there was good reason to believe that more than 90 per cent of all deaths were being registered. At first the registration area included only two states, Massachusetts and New Jersey, and certain cities in other states. The area has gradually expanded as shown by the following tables. In studying the mortality rates of the country in the published reports it is important to keep in mind this addition of new territory, new populations, from year to year.

TABLE 19

REGISTRATION AREA FOR DEATHS

Year.	Population		Land area.	
	Number.	Per cent of total	Square miles.	Per cent of total.
(1)	(2)	(3)	(4)	(5)
1880	8,538,366	17.0	16,481	0.6
1890	19,659,440	31.4	90,695	3.0
1900	30,765,618	40.5	212,621	7.1
1901	31,370,952	40.3	212,770	7.2
2	32,029,815	40.4	212,762	7.2
3	32,701,083	40.4	212,762	7.2
4	33,345,163	40.4	212,744	7.2
5	34,052,201	40.4	212,744	7.2
6	41,983,419	48.9	603,066	20.3
7	43,016,990	49.2	603,151	20.3
8	46,789,913	52.5	725,117	24.4
9	50,870,518	56.1	765,738	25.7
1910	53,843,896	58.3	997,978	33.6
11	59,275,977	63.1	1,106,734	37.2
12	60,427,247	63.2	1,106,777	37.2
13	63,298,718	65.1	1,147,039	38.6
14	65,989,295	66.8	1,228,644	41.3
15	67,336,992	67.1	1,228,704	41.3
16	71,621,632	70.2	1,307,819	44.0
17	75,306,588	72.7	1,349,506	45.4
18	81,786,052	77.7	1,546,166	52.0

TABLE 20

LIST OF STATES IN THE REGISTRATION AREA FOR DEATHS

Year of Entrance.	State	Year of Entrance.	State.
(1)	(2)	(1)	(2)
1880	Massachusetts	1910	Minnesota
	New Jersey		Montana
	District of Columbia		Utah
1890	Connecticut	1911	Kentucky
	Delaware (dropped in 1900)		Missouri
		1913	Virginia
	New Hampshire	1914	Kansas
	New York	1916	North Carolina
	Rhode Island		South Carolina
	Vermont	1917	Tennessee
1900	Maine	1918	Illinois
	Michigan		Oregon
	Indiana		Louisiana
1906	California	1919	Delaware
	Colorado		Florida
	Maryland		Mississippi
	Pennsylvania	1920	Nebraska
1906	South Dakota (dropped in 1910)		
1908	Washington		
	Wisconsin		
1909	Ohio		

As a result of a test of the completeness of the registration of deaths in Hawaii the territory was admitted to the registration area for deaths for 1917, thus extending beyond the Continental United States the area from which the Bureau of the Census annually collects and publishes mortality statistics. The population and land area of Hawaii are *not* included in the figures of the above table.

The states in which the registration of deaths is still too unsatisfactory to warrant inclusion in the registration

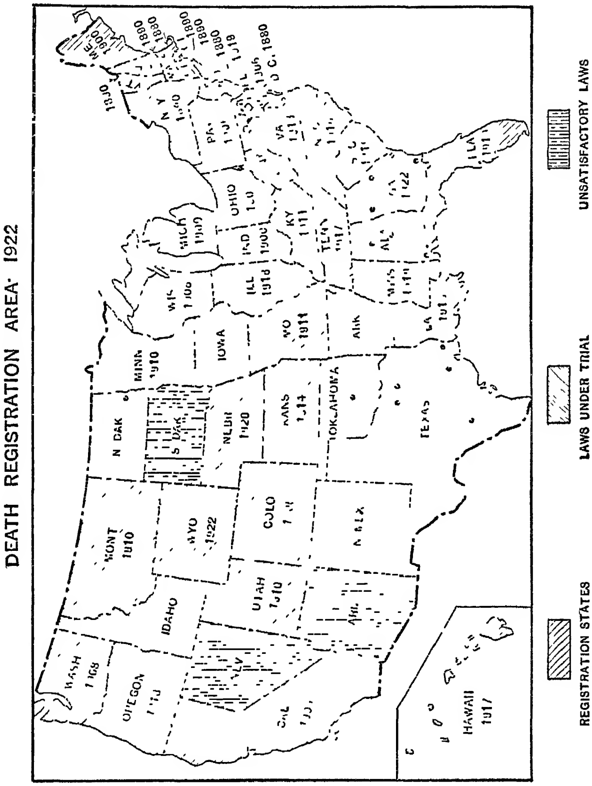


FIG. 29.—Registration Area for Deaths.

area are: Alabama, Arizona, Arkansas, Georgia, Idaho, Iowa, Nevada, New Mexico, North Dakota, Oklahoma, South Dakota, Texas, West Virginia, and Wyoming. (1920.)

United States registration area for births. — A registration area for births was not established until 1915. For this year the Bureau of the Census published its first annual report of birth statistics based on registration records. The birth statistics published in connection with the regular decennial reports from 1850 to 1900 inclusive were based on enumerator's returns.

The registration area in 1915 included only ten states — Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New York, Pennsylvania, Michigan, Minnesota, and the District of Columbia. In these states the registration of births is believed to include upwards of ninety per cent of the actual numbers. This registration area includes only 10 per cent of the area and 31 per cent of the population of the country. In spite of this unfavorable showing a beginning has been made, and inasmuch as the standard birth certificate has been adopted for 85 per cent of the population and as public sentiment in regard to the importance of vital statistics is rapidly gaining ground, it is likely that the registration area for births will rapidly extend. No state is admitted until the accuracy of its records have been submitted to test.

In 1916, Maryland was added. In 1917, Virginia, North Carolina, Kentucky, Indiana, Ohio, Wisconsin, Washington, Utah and Kansas; in 1919, California, Oregon and South Carolina; in 1920, Nebraska, was added, bringing the population included up to 59.8 per cent.

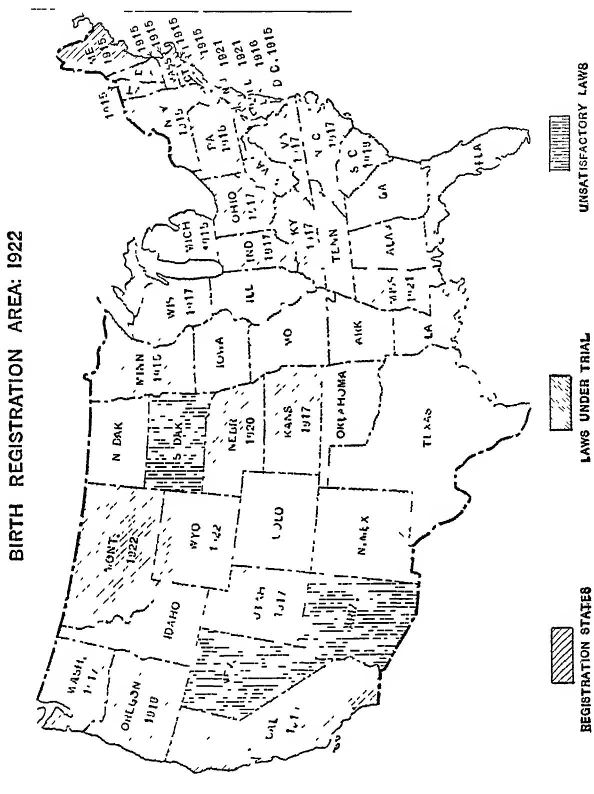


FIG. 30.—Registration Area for Births.

Need of national statistics. — More and more it becomes obvious that there is need of a national system of keeping records of vital statistics, with uniform state laws, and with proper provision for the local use of the data registered. The excellent work done by the Bureau of the Census has done much to emphasize this need. Likewise interstate barriers must be broken down in the interest of suppressing diseases dangerous to the public health. The U. S. Public Health Service, keeps a record of cases of diseases from data furnished by the states and publishes the same in its weekly Public Health Reports. This is only a part of what is needed. If the time ever comes when the United States establishes a real National Health Department the maintenance of an adequate system of vital records will be one of supreme importance.

Registration in other countries. — Although it is the duty of American physicians and health authorities to conform to existing laws and to strive for uniformity on the basis of the model laws, it is not at all certain that the models already set up are the best that can be obtained. It is a well-known fact that physicians are not always frank in reporting the causes of death. For personal reasons or for the protection of their clients the true facts are sometimes concealed. Professional secrecy, while it is not carried as far in European countries, is yet a material element in the statistical problem. It is well, therefore, to study the statistical methods of other countries, because much can be learned from their failures and successes.

In France the methods followed are those of the Civil Code of Napoleon. The statistics are kept in each commune by the Bureau de l'Etat Civil. The cause of death is usually based on the statement of the physician, sometimes given verbally, but very often on the statement of the informant, that is, the head of the family, husband or wife, the nearest relative of the deceased present in the locality, etc. There is no secrecy about this method, and no legal obligation on the part of the physician; consequently the French statistics are not as reliable as they ought to be. In Belgium and Holland the system is much the same as in France.

In England and Wales the registration system is much better, but is very inelastic because the complete details of procedure were incorporated in Acts of Parliament which cannot easily be changed. As an example of this inelasticity, the act declares that no still-born children shall be registered at all. The country is divided into registration districts and sub-districts and the registrars in charge are responsible for getting the statistics in their respective districts. The data in regard to deaths must be submitted to the registrars by informants, who receive from the attending physician a statement as to the cause of death made out in accordance with prescribed forms. The legal periods allowed for registering deaths are very long, but practically, through the energy of the registration service, fairly prompt reports are received.

The Swiss system has some decided advantages over those of other European countries and even over that of our own country. Hence it deserves more than passing notice.

The Swiss system of registration.* — The Swiss system of reporting deaths is so arranged that the desired statistical data are assured, the statistical facts are not associated in the statistician's office with the name of the decedent, and the facts as to the cause of death are confidential between the physician and the government.

The death-certificate is a card (white for males, yellow

* From information furnished by Mr. Thomas J. Duffield.

for females, and orange for still-births) which has three parts, an upper part which bears only the name of the decedent, a middle part which includes personal and statistical particulars required for a study of deaths by time, place, profession, etc., and a lower part which states the cause of death, with primary and contributory causes, statement of whether or not, an autopsy was held and a statement of the sanitary condition of the place of death.

There are four parties involved: first, the person responsible for notifying the local civil authority of the death, namely the (1) head of the family, (2) husband or wife, (3) nearest relative of the deceased present in the locality; second, the local civil authority; third, the physician in charge or, in the absence of a physician, a medical examiner appointed by the government; and fourth, the Central Bureau of Statistics.

The modus operandi is as follows: — The name is written on Part I, and Part II is filled out by the responsible person, who sends the card to the local authority. The local authority records the fact of the person's death, the date of death, etc., places a number on Part II and sends the card to the physician. The physician fills out Part III; detaches Part I, *i.e.*, the name, and throws it away; puts the card into an envelope on the outside of which he places the assigned number and returns it to the local authority. The local authority checks off the number to show that the physician has done his duty, and without opening the envelope sends it to the Central Bureau of Statistics. Thus the name of decedent does not go to the statistical bureau and the medical data have no local record. It is possible, however, in case of legal necessity to connect all the facts through the local authority where the name and number are recorded together.

This system at first appears cumbersome, but really it is not. The larger cities send their cards to the Statistical Bureau weekly; the smaller ones, monthly. The causes of death are carefully studied by a physician of the bureau, and if the physician's records are not clear, follow-up letters are sent out and the necessary data secured before the statistics are made up.

The advantage of the confidential system of reporting the causes of death may be seen from the fact that when about the year 1891 this system was put in use in certain cantons, the number of reported deaths from syphilis was nearly doubled. Physicians like the system, for they have less clerical work to do. They receive no fee for their returns, but as a recompense the weekly demographic and sanitary bulletin is sent to them without charge. The system has been used throughout Switzerland since January 1, 1901.

An objection to the plan is that the local health authority is not kept in as close touch with epidemic conditions as in the United States. It would be possible to modify the system so as to bring this about.

Part I Nom de la décédée: ....
....

La notice pour les officiers de l'état civil se trouve au verso.

Part II Le médecin est prié de bien vouloir: 1° répondre le plus tôt possible aux questions 8 à 10, en tenant compte des **observations inscrites au verso**, mais seulement après l'autopsie, si celle-ci a lieu; 2° contrôler les réponses données aux questions 1 à 7 par l'officier de l'état civil et, cas échéant, les compléter; 3° après avoir enlevé le présent coupon, mettre le bulletin dans l'enveloppe ci-jointe, fermer cette dernière et la mettre **sans retard** à la poste.

Féminin.

Registre des décès A 191..

Arrond^t d'état civil: ....

District: ....

No. ....

Part III

1. Décédée le .... à ... heures {matin / soir*}
2. Lieu du décès (Commune): ....
   (Quart. etc. hôp., établ., etc.) ....

Pour les non domiciliées au lieu du décès, durée du séjour: ....

3. Profession de la décédée: ....
   Position dans l'entreprise: ....
   Nature de l'entreprise. ....
   Si la défunte a moins de 15 ans, **profession du père*** ou **de la mère***. ....
4. Etat civil: célibataire* — mariée* — veuve* — divorcée*.
   P^r les enfants au-dessous de 5 ans: légit.*—illég.*—mise en pension.*
5. Commune d'origine. .... (Canton, Etat.) ....
6. Commune de domicile: ....
7. Née le .... 1 ...

Part IV

8. **Déclaration medicale de la cause du décès:**

a. Maladie primitive ou cause primaire (*En cas de mort violente, indiquer le genre et la cause*) ....

b. Maladie conséc. et cause immédiate de la mort } ....
....

c. Maladies concomit. ou circonst. dignes d'être mentionnées } ....
....

9. Autopsie Oui* — Non.*

10. Condit. sanit. de l'habitation: ....
    (Voir au verso.)

Le médecin traitant* — appelé après la mort*:

(*Sig.*) .... à ..

* Souligner les mots qui se rapportent à la personne.

136

Notice pour l'officier de l'état civil.

Tôt après l'annonce d'un décès, c.-à-d. la réception d'une déclaration de décès, l'officier de l'état civil remplit la carte de décès jusques et y compris la question 7. Cette carte est immédiatement envoyée dans une enveloppe double au **médecin qui a traité la malade**, ou, si un traitement médical n'a pas eu lieu, au **médecin appelé après le décès. Dans la règle**, la carte de décès doit, **dans les 48 heures**, être de nouveau entre les mains de l'officier de l'état civil, qui l'adresse au bureau fédéral de statistique

Si la cause du décès ne peut être certifiée par un médecin **patenté**, parce qu'un traitement médical n'a pas eu lieu et qu'une attestation médicale du décès a fait défaut, l'officier de l'état civil l'indiquera, en réponse à la question 8, et mentionnera le motif de l'absence de certificat médical.

Observations pour le médecin.

Question 8. On doit distinguer avec soin ce qui est **maladie primaire** ou **causale** (8 a) et ce qui est **maladie consécutive** ou **secondaire** (8 b).

La question 8 a est importante au point de vue de l'hygiène et de la police sanitaire, mais il est souvent difficile d'y répondre; parfois la réponse est incertaine et même **impossible** à donner Dans ce dernier cas, on fera un trait en regard de la question 8 a et, si la réponse est incertaine, on ajoutera un point interrogatif.

En cas de MORT VIOLENTE, il importe d'en indiquer exactement la nature, la cause et la date, et d'indiquer en même temps s'il s'agit d'un suicide (motif: maladie mentale, alcoolisme, etc.), d'un homicide ou d'un accident.

Il est en général plus facile de répondre à la **question 8 b, car il** s'agit le plus souvent de cas que le médecin a pu observer pendant la vie ou après le décès (autopsie? question 9) On indiquera ici les **suites d'accidents**, p ex la nature et le siège des lésions, fractures, luxations, affections cérébales, inflammations secondaires, etc.

Question 8 c. Ici on indiquera les conditions pathologiques qui accompagnaient la maladie principale et qui ont exercé une influence sur le cours et l'issue de cette dernière, comme, par exemple, les déviations de la colonne vertébrale dans les affections du poumon et du cœur, l'alcoolisme dans les maladies aigues, les maladies mentales, etc.

Question 10. Ici on indiquera les conditions sociales et les conditions sanitaires de l'habitation Ces dernières sont surtout désirables dans tous les cas où la mort a été causée par une maladie épidémique, contagieuses ou tuberculeuse

Les points à considérer sont:

I. Locaux habités: 1° Dimensions; 2° Exposition au soleil; 3° Ventilation; 4° Chauffage; 5° Humidité causée par une construction défectueuse; 6° Humidité causée par un usage abusif (chambres employées pour cuire les aliments, laver le linge); 7° Propreté, etc.

II. Chambres à coucher: les mêmes 7 points.

III. Eloignement des immondices: 1° Latrines; 2° Eaux ménagères.

IV. Alimentation d'eau potable.

Lorsqu'une habitation présente des défectuosités sur l'un ou l'autre de ces points, il faudra l'indiquer en se servant à cet effet des chiffres romains et arabes qui se rapportent au cas particulier, en tenant compte toutefois des circonstances spéciales, selon que la maison est située à la ville ou à la campagne, comme, par exemple·

Défectuosités: I, 1, 3, 6, 7; II, 2, 3, 4, 7; III, 1.

ou bien Défectuosités: I, 2, 4; IV (puits), etc.

Statistics dependent on registration. — It ought not to be necessary to emphasize the fact that statistics of births and deaths are reliable only as registration is reliable. We are in the habit of pointing with pride to the long statistical records of births and deaths in European countries; but we must not overlook the fact that while the tabular work is often splendidly done the figures themselves are subject to many errors, some of which have just been pointed out. The basis of good statistical reasoning must always be "the facts, all the facts and nothing but the facts."

EXERCISES AND QUESTIONS

1. Compare the methods of enumeration used in taking the U. S. census of 1920, with those used in 1910, 1900, 1890, 1880, etc.

2. How do these methods compare with those used in England, France, Sweden?

3. Would there be any advantage in making the census date, "as of January first?"

4. What advantages would come from the adoption of a uniform census date for the entire world?

5. How accurately is the population of China known?

6. To what extent is the keeping of accurate census records and records of vital statistics an index of national progress?

7. How can improvements be made in ascertaining the facts concerning morbidity?

CHAPTER V

POPULATION

Estimation of population. — It is only for the census years that populations can be known with certainty. For the intercensal years, the years between two censuses, it is necessary to depend upon estimates. This is also the case for the postcensal years, namely, the years following the last census. These estimates are only approximately true, a fact which must not be forgotten, but they are sufficiently near the truth for many practical uses.

Estimations of population may be made in various ways. The natural growth of population is like that of money at compound interest except that the interest is being added constantly instead of semi-annually or quarterly. Mathematicians call this geometrical progression. With a given constant rate of interest money in the bank increases more and more each year. It is the same with population. In geometrical progression the basis of our population estimates is the annual *rate* of increase. When dealing with very large populations, and especially when dealing with populations not influenced by emigration or immigration, this method is the most accurate one to use. It has several practical disadvantages, however, and in the present shifting condition of the world's population there are not many places where the natural growth of population is the only factor to be considered.

A simpler method is that of arithmetical progression, which assumes a constant annual increment between two census years. The increase in ten years divided by ten gives the annual increase. This is practically the method by which money increases by simple interest. The arguments in favor of this method of estimating population are that it is simple and easily understood; that in view of the various disturbing factors due to migration and other causes it gives results practically as near the truth as those obtained by geometrical progression; that the estimates for the whole area of a given district will be equal to the sum of the estimates for all the parts of the district, which would not be the case with the geometrical method. The U. S. Bureau of the Census has adopted this method, and in the interest of uniformity all cities and states should do the same. The method is one which should not be extended far into the future. In vital statistics it is not necessary to extend it beyond ten years from the last census, for ten years always brings another census.

Another method is that of using local data as indices — such as the number of registered voters, the number of new building permits, the number of school children, the number of names in the directory, the bank clearings, the number of passengers carried by the trolley cars, the number of deaths from non-communicable diseases, etc. These facts are often obtainable for each year and serve as valuable checks on the census method, but as a rule they should not be depended upon alone. Common sense must be used. What is wanted are the facts, and rigid adherence to a rule when the result is manifestly unfair is absurd. When deviations from accepted practice are made, however, a statement of the method of making the estimates of the population should always accompany the result. Even the U. S. Census utilizes local data to modify its estimates where plainly necessary. Perhaps this practice might be used more frequently with advantage.

Estimates of population might be made from records of births and deaths if these were accurately kept and if the migrations of the people were known. Practically this method is useless.

One item in connection with the estimation of the population of cities should not be lost sight of, namely, that of changing boundaries. Cities often grow by extending their area. Increases of population from this cause should not be mistaken for natural increase in population.

Arithmetical increase. — Let us assume that the population of a place in 1900 was 70,000 and in 1910, 100,000. The increase was, by the arithmetical method, 30,000 in ten years, or 3000 in each year. For 1904, therefore, the estimated population would be 70,000 plus four times 3000 or 82,000; and for 1915 it would be 100,000 plus five times 3000 or 115,000. It is assumed that within the ten years following the last census the annual increase will be the same as the average annual increase between the last two censuses. This is the simple and customary way of making the estimates.

It must be remembered that between these particular censuses the interval was not exactly ten years. The census of 1900 was "as of June 1st," that of 1910 "as of April 15th." Consequently, the interval was ten years less a month and a half or $9\frac{7}{8}$ years ($=9.875$ years). The average increase was not, therefore, 3000 per year, but $30{,}000 \div 9.875$ or 3038. This would make the estimated population 82,152 for 1904 and 115,190 for 1915. It will be seen that this difference is not great. Nevertheless, it is a correction which in some cases is of importance. Whether it will have to be made after the next census will depend upon the date decided upon. Strictly speaking, the populations of the census years should be adjusted to the middle of the year before the average annual increments are computed.

Adjustment of population to mid-year. — The census of 1910 was "as of April 15th." What then was the population on July 1st?

On June 1, 1900, the population was 70,000. The average annual increase was 3038 per year, or 3038 ÷ 12 = 253 per month. On July 1, 1900, the population was, therefore, 70,000 + 253 = 70,253. On July 1, 1910, it was 100,000 + 253 × $2\frac{1}{2}$ months or 100,633. The increase in ten years was, therefore, 100,633 − 70,253 = 30,380, or 3038 per year, as before.

This arithmetical method, therefore, is used in adjusting the population for the census years from the day on which the census was actually taken to the mid-year.

For example, on June 1, 1900, the population of the state of Indiana was 2,516,462; on Apr. 15, 1910, it was 2,700,876, an increase of 184,414 in 118.5 months. On July 1, 1910, *i.e.*, 2.5 months later than the census date, the estimated population would therefore be $2{,}700{,}876 + \frac{2.5}{118.5} \times 184{,}414$ or 2,704,767. This is the figure used by the U. S. Census in the Mortality Report of that year.

Let us take a more recent example. On Apr. 15, 1910, the population of New York State was 9,113,614; on Jan. 1, 1920 it was 10,385,227, a gain of 1,271,613 in 116.5 months. The estimated population for July 1, 1920, would be, therefore, $10{,}385{,}227 + \frac{6}{116.5} \times 1{,}271{,}613$, or, by slide rule computation, about 10,451,000, a figure near enough for the computation of death-rates.

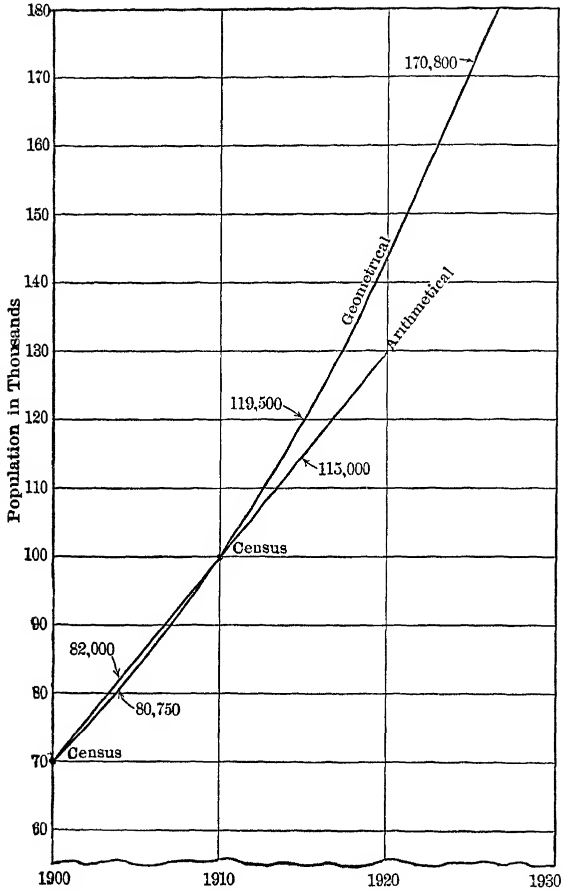
Geometrical increase. — A simple rule for computing populations by the geometrical method is to use the logarithms of the populations concerned in the same way that the populations are used in computing by the arithmetical method. Let us assume, as before, that the population was 70,000 in 1900 and 100,000 in 1910. The logarithm of 100,000 is 5.0000, that of 70,000 is 4.8451. Instead of subtracting 70,000 from 100,000 we subtract 4.8451 from 5.0000 and get 0.1549. Instead of dividing 30,000 by 10 we divide 0.1549 by 10 and get 0.01549. Then we multiply this by 4 and get 0.0620. Finally, we add this to 4.8451, which is the log of 70,000, and get 4.9071. This is the log of the answer, which is 80,750. The following comparison ought to make this clear:

Example. — The population of a city in 1900 was 70,000 and in 1910, 100,000. What was the population in 1904, in 1915 and in 1925?

TABLE 21

	Arithmetical method	Geometrical method.
(1)	(2)	(3)
Population in 1910	100,000	log of 100,000 = 5 0000
" " 1900	70,000	" " 70,000 = 4 8451
Increase in 10 years	30,000	0 1549
Increase in 1 year	3,000	0 0155
Increase in 4 years	12,000	0 0620
Population in 1900	70,000	4 8451
" " 1904	**82,000**	log of **80,750** = 4 9071
Increase in 5 years	15,000	0 0775
Population in 1910	100,000	5 0000
" " 1915	**115,000**	log of **119,500** = 5 0775
Increase in 15 years	45,000	0 2325
Population in 1910	100,000	5 0000
" " 1925	**145,000**	log of 170,800 = 5 2325

It will be noticed that for intercensal years the arit ical method gives higher estimates than the geoms.) but that for postcensal years the geometrical res ms can higher. This is illustrated graphically by Fig. 31. take the



31.—Example of Arithmetical and Geometrical Methods of Estimating Population.

Formula for geometrical increase. — The mathematical formula for geometrical increase is

$$P_n = P_c\,(1 + r)^n,$$

in which P_c is the population at one census, P_n is the population n years after P_c, r is the annual rate of increase and n is the number of years.

Let us apply this to the case already considered. Here we know the two populations P_c and P_n, 70,000 and 100,000, and we know that n is 10 years; first we need to find r, the annual rate of increase. According to algebra we may rewrite the above formula, thus:

$$\log P_n - \log P_c = n \log (1 + r).$$

Substituting the values of the logarithms of 100,000 and 70,000 and the value of n we have

$$\begin{aligned} 5.0000 - 4.8451 &= 10 \log (1 + r) \\ 0.1549 &= 10 \log (1 + r) \\ 0.01549 &= \log (1 + r) \end{aligned}$$

and from the tables of logarithms $(1 + r)$ is found to be 1.036, hence $r = 1.036 - 1 = 0.036$, or 3.6 per cent. Therefore, the average annual rate of increase between 1900 and 1910 was 3.6 per cent.

Knowing this rate and assuming it to be constant we can find the population in any other year. Suppose we try 1925, 15 years after 1910. Then we have:

$$\begin{aligned} P_n &= 100{,}000\,(1 + 0.036)^{15}, \\ \log P_n &= \log 100{,}000 + 15 \log 1.036 \\ &= 5.0000 + 15 \times 0.01549, \\ \log P_n &= 5.23235, \\ \therefore\ P_n &= 170{,}790 \text{ (according to the log. tables.)} \end{aligned}$$

By the use of this formula many interesting problems can be solved. For example, how many years would it take the population in our now familiar example to reach 200,000? We know that the average rate of increase between 1900 and 1910 was 3.6 per cent. Therefore, we have in the formula

$$200{,}000 = 100{,}000\,(1 + 0.036)^n.$$

We want to find the value of n. We have

$$\begin{aligned}
\log 200{,}000 &= \log 100{,}000 + n \log 1.036,\\
5.30103 &= 5.0000 + n \times 0.01549,\\
0.30103 &= n \times 0.01549,\\
n &= \frac{0.30103}{0.01549} = 19.43 \text{ years.}
\end{aligned}$$

Strictly speaking, we have no reason to use a year or even a month as the basis of compounding, as the population is increasing from day to day and from hour to hour. A more accurate formula may be found in books on calculus. We do not need to use it in this work.

Rate of increase. — The population of the United States on June 1, 1900, was 75,994,575; On Apr. 15, 1910, it was 91,972,266. The increase in $9\frac{7}{8}$ years was 15,977,691 or, 134,833 per month, assuming the increase to have been constant. We might divide this still further and say that the average increase was 4494 per day, or about 3.12 persons per minute. On this basis we might also by computation ascertain that the population of the United States passed the one hundred million mark at 4 o'clock on Apr. 3, 1915. Such statements as this have a fascination for certain people, but they are of idle moment. They merely serve to illustrate the method of computation by the arithmetical method. Had the geometrical method been used the result would have been different. As a matter of fact no one will ever know just when the population passed the hundred million mark.

If we take the above figures for 1900 and 1910 and regard them as representing a ten year period (instead of 9.875

years), the increase amounts to $\frac{15{,}977{,}691}{75{,}994{,}575}$, or 21 per cent. We may divide this by 10 and say the annual *increment* was 2.1 per cent, or more accurately by 9.875 and say that it was 2.13. But we ought not to use the word *rate* in this connection. As a matter of fact, if the rate of increase in 10 years was 21 per cent, the average annual rate would not be 2.1 per cent. If in the formula for geometrical increase we let $P_c = 100$ and $P_n = 121$, which would represent an increase of 21 per cent in 10 years, then

$$\log 121 - \log 100 = 10 \log (1 + r),$$
$$2.08278 - 2.00000 = 10 \log (1 + r),$$

from which

$$r = 1.92 \text{ per cent, not } 2.1 \text{ per cent.}$$

This assumes that, as we might say, the interest is compounded annually.

This error of dividing the percentage increase in 10 years by 10 to find the annual increase is sometimes made in using the geometrical method of estimating increase. Obviously with compound interest a lower rate suffices to produce a given increase in 10 years than with simple interest. The proper way to find the annual rate is by the use of the formula.

In 1920 the population of the United States was 105,710,620, an increase of 15.2 per cent in ten years less 3.5 months. This is equivalent to 1.27 per cent annually, a much lower rate than the preceding.

Decreasing rate of growth. — It seems to be generally true that as cities become larger their annual *rate* of growth decreases. A study of six American cities gave the following annual rates of increase when the populations were as indicated.

TABLE 22

DECREASING RATE OF GROWTH OF CITIES

Stage of Population	Annual percentage Increase
(1)	(2)
100,000	4 85
200,000	3 59
300,000	2 91
400,000	2 48
500,000	2 02
600,000	1 75
700,000	1 66
800,000	1 58

This seems to be so generally true that it may be put down as a law that as cities become larger their annual percentage rates of growth fall off. At the same time this may be accompanied by an increasing annual increment of population.

Difference between estimate and fact. — In estimating the population either by the arithmetical or geometrical method we are assuming something which is almost never true, *i.e.*, that the population is increasing *regularly*. As a matter of fact the increase is not regular from year to year. Therefore, any estimate may be erroneous. In the absence of the facts, however, we are compelled to resort to the method of estimation. Also when we assume that the growth in the present decade is the same as in the last decade we assume a uniformity of conditions which seldom obtains. Let us check a few of our estimates by actual census returns.

In Cambridge, Mass., the census population was 70,028 in 1890 and 91,886 in 1900, a gain of 21,858 in the decade. If the same increase had continued during the next decade the population would have been 113,744. The census of 1910 was, however, only 104,839.

In Detroit, Michigan, the population in 1890 was 205,876 in 1900 it was 287,704, the increase being 79,828. If this increment continued regularly the population in 1910 would have been 365,532; actually it was 465,766. This of course is an extreme case. In most cities the estimates agree fairly well with the facts.

Let us take the case of a larger population, say that of the United States. In 1890 the population was 62,947,714, in 1900, 75,994,575, the decadal increase, 13,046,861. The estimate for 1910 based on these figures would have been 89,041,436 by arithmetrical, or 91,723,000 by geometrical increase. Actually the population in 1910 was 91,972,266. For large populations like this the geometrical method gives closer results. The Great War upset population estimates to a great extent. In the United States the results of the last census were disappointing to many cities and there were many complaints that errors of count had been made. The war conditions coupled with the fact that the census interval was about three per cent less than ten years seems sufficient to account for the smaller growth in most places.

Revised estimates. — Suppose, however, that as in Cambridge, Mass., the census of 1910 showed that the city had not grown as fast as in the decade from 1890 to 1900, what shall be done with the estimates already made for the years 1901 to 1909, inclusive? Obviously they were not correct even on the theory of steady increase. Yet they have been used as the basis of computing birth-rates and death-rates. The answer is that if the discrepancy is large the populations for those years should be reëstimated and the birth-rates and death-rates recomputed. Let us see what differences would result.

TABLE 23

REVISION OF POPULATION ESTIMATES

Year.	Census.	Postcensal estimate based on 1890–1900	Intercensal estimate based on 1900–1910
(1)	(2)	(3)	(4)
1890	70,028		
1900	91,886		
1		94,072	93,181
2		96,258	94,476
3		98,444	95,771
4		100,630	97,066
5		102,816	98,361
6		105,002	99,656
7		107,188	100,951
8		109,374	102,246
9		111,560	103,541
10	104,839		

Ordinarily the errors are not as great as this and no correction need be made, but the chance of error is so great that old published figures for death-rates should not be accepted at their face value until the population estimates have been carefully examined for errors of this sort.

It would be sound practice to revise all rates based on postcensal population estimates every ten years, *i.e.*, after each new census.

Estimation of population from accessions and losses. — In a place where records of the births and deaths are accurately kept it would be possible to use them in estimating population, but emigration and immigration enter as disturbing factors. Two examples of this method will illustrate the way in which this method works out.

In England and Wales the data were as follows:

Population in 1891	29,000,000
Births, 1891 to 1901	9,160,000
	38,160,000
Deaths, 1891 to 1901	5,560,000
Computed population in 1901	32,600,000
Census gave, for the year 1901	32,530,000
Difference representing excess of emigration over immigration	70,000

In Massachusetts the population for 1910 computed in this way was 3,092,349, but the census gave 3,366,416, an excess of 274,067, which represented in part the excess of immigration over emigration and in part, no doubt, incomplete registration of births. In 1920, the excess was only half as much as in 1910, due, no doubt to a lower immigration.

Immigration. — The irregular effect of immigration in the United States may be inferred from Fig. 32, which shows the immigration by years from 1820 to 1920. Immigration has occurred in a series of waves, resulting from the relative economic conditions in this country and abroad. When this incoming population has been concentrated in manufacturing cities, as has periodically been the case, it has been followed by an increased prevalence of disease. The subject is, therefore, an important one for sanitarians to consider.

The data for immigration are published in the annual reports of the U. S. Commissioner General of Immigration.

Accuracy of state censuses. — The U. S. Bureau of the Census does not recognize as generally acceptable the results obtained by those states which enumerate their populations in the years which end in 5, on the ground that it does not control such intermediate censuses and has no way of assuring itself of their accuracy. On the whole this position is probably sound. In Massachusetts, the federal census in

1910 was made by the same state authority, namely the Director of the Massachusetts Bureau of Statistics, which has made the state census, and one census was presumably as

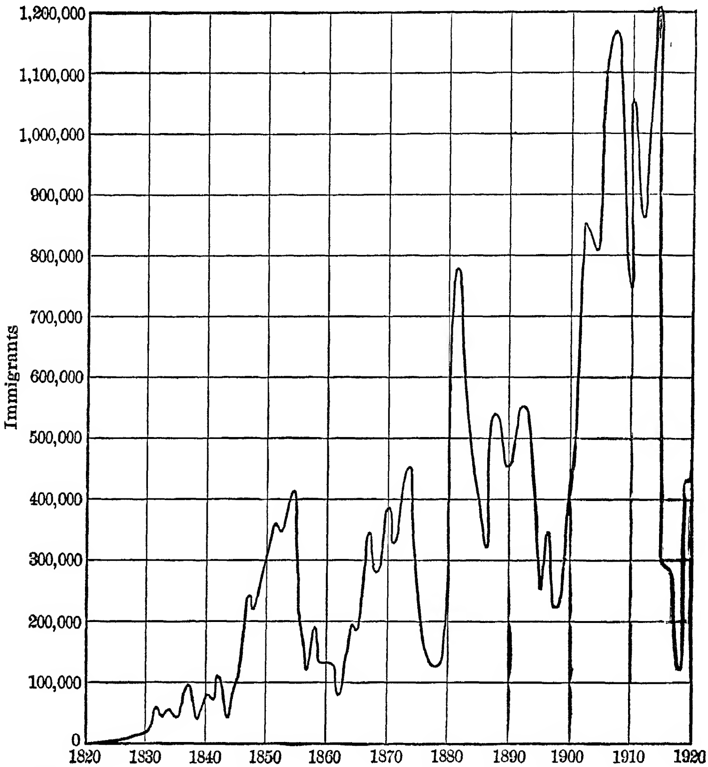


FIG. 32. — Immigration to the United States: 1820–1920. (From report of Commissioner of Immigration.)

accurate as the other. The census of 1920 was made directly by the federal authorities.

In the past, however, the state censuses have evidently not been as accurate as the federal censuses. If the results of the federal censuses for Massachusetts are plotted the points fall on quite a smooth and regular curve from 1820 to 1920, the only important departure being during the decade of the Civil War. The figures for the state censuses do not all fall on this line, but rise and fall irregularly. This is presumptive, though not conclusive, proof of the inaccuracy of some of the figures (Fig. 33).

The Massachusetts state census was taken on May 1 from 1855 to 1905, inclusive; in 1915 it was taken on April 1.

The question often comes up for decision, shall the state censuses be used in estimating populations for the years in the last half of each decade? For the sake of uniformity it is best to use the federal figures only unless the Bureau of the Census maintains some supervision over the state census, in which case they should be given full weight. The state figures should be used, in any case, as a check on the estimates based on the federal results. Should glaring differences be noticed their cause should be investigated. If state figures are used this fact should be stated in connection with the estimate.

Urban and rural population. — It is common to classify the population of a country into "urban" and "rural." This is done for purposes of discussion, the idea being to separate the people living in sparsely settled regions and small villages from those living in cities, on the theory that the former lead a more individualistic life, while the latter lead a more communal life. In cities for example, water supplies, sewerage systems, food supplies, methods of transportation and various public utilities are used in common by all, while in the country each household has its own well, its own garden, its own cesspool, its own means of transportation. Thus urban and rural populations are supposed to live and work under different conditions.

Obviously the separation of the two classes must be an arbitrary one. In the United States prior to the Census of 1880 the limit of 8000 inhabitants was used. In 1880 it became recognized that many communities of less than 8000 inhabitants possessed "the distinctive features of urban life," and accordingly the limit was dropped to 4000, although the old limit was used in many of the tabulations of the

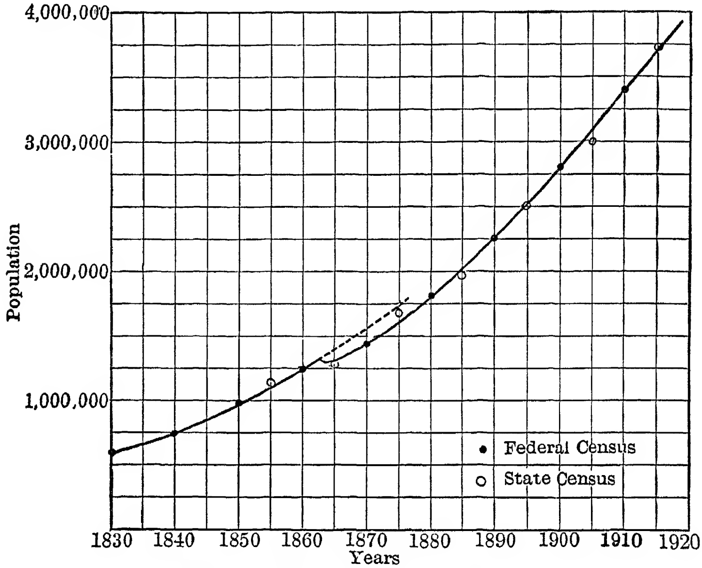


Fig. 33. — Population of Massachusetts according to Federal and State Censuses. (The effect of the Civil War should be noticed.)

census of that year, and also of the years 1890 and 1900. In 1900 some comparisons of the two limits were made. It was found, for example, that 32.9 per cent of the population of the United States would be classed as urban on the basis of the 8000 limit, and 37.3 per cent, on the basis of the 4000 limit.

In 1910 the limit was reduced by the Census Bureau to

2500. The reason for this probably lay in the extension of various public utilities, once existing only in the cities of larger size, to the smaller communities. In 1910, 46.3 per cent of the population were classed as urban on the basis of the 2500 limit, but only 38.8 were in cities larger than 8000. In 1920 the 2500 limit was maintained and it was found that on this basis 51.4 per cent of the population of the United States was urban.

One must be careful in drawing conclusions from "urban and rural statistics." In the first place, of necessity they relate to civil divisions. "Outside of New England," says the Census Report for 1900, "there is not much difficulty in distinguishing between the urban and rural elements of the population, as only dense bodies of population are chartered. But in New England a town, which is the usual division of the county, is chartered bodily as a city when certain conditions of population are fulfilled, so that a city may contain a considerable proportion of rural population, and, conversely, a town may contain a compact body of population of magnitude sufficient to be classed as urban." Evidently then, rural population does not necessarily mean people living in isolation, as on a farm. Almost every incorporated town or borough has some center, and here people may live under communal conditions which may be quite as insanitary as those found in cities, with houses close together, with boarding houses, saloons, stables, numerous cesspools, and even sewers and public water supplies.

Attempts have been made by various writers to make a triple separation of the population into "rural," "village," and "urban," using populations of 1000 and 4000 as demarkations. These add but little to the value of the statistics and usually it is best to follow the practice of the Bureau of the Census. Populations of 3000 and 5000 have also been used as limits between rural and urban. Whatever limits are used the possible fallacies inherent in an arbitrary classification should be kept in mind.

In comparing conditions as shown by censuses ten years apart there is always likely to be some confusion caused by communities which have populations near the limit changing from one side to the other. The Bureau of the Census has followed this practice: " In order to contrast the *proportion* of the total population living in urban or rural territory the territory is classified according to the conditions as *they existed at each census;* but in order to contrast between the *rate of growth* of urban and rural communities it is necessary to consider the changes of population for the *same territory,* which have occurred between censuses, and the places included in the urban class are those which have populations above the limit at the last census, even though they were below the limit at the time of the previous census.

Since about 1820 the urban population of the country has been rapidly increasing, the rural population becoming relatively less. This is well shown by the following figures:

TABLE 24

TOTAL AND URBAN POPULATION AT EACH CENSUS: 1790–1920

(From U. S. Census, 1920, Vol. 1, p. 43.)

Census year.	Total population.	Urban population.*	Number of places.	Per cent of urban of total population.
(1)	(2)	(3)	(4)	(5)
1790	3,929,214	131,472	6	3 3
1800	5,308,483	210,873	6	4 0
1810	7,239,881	356,920	11	4 9
1820	9,638,453	475,135	13	4 9
1830	12,866,020	864,509	26	6 7
1840	17,069,453	1,453,994	44	8 5
1850	23,191,876	2,897,586	85	12 5
1860	31,443,321	5,072,256	141	16.1
1870	38,558,371	8,071,875	226	20.9
1880	50,155,783	11,365,698	285	22.7
1890	62,947,714	18,244,239	445	29.0
1900	75,994,575	25,018,335	547	32.9
1910	91,972,266	35,570,334	768	38.7
1920	105,710,620	46,307,640	924	43.8

* Population of places of 8000 or more at each census.

This is also shown by the increase in the number of large cities since 1860.

TABLE 25

TABLE SHOWING THE INCREASE IN NUMBER OF LARGE CITIES IN THE UNITED STATES BETWEEN 1860 AND 1910

Number of cities with population above.	1860	1870	1880	1890	1900	1910	1920.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
25,000	32	50	77	125	161	229	287
50,000	15	24	35	58	79	109	144
100,000	8	13	20	28	38	50	68
500,000	2	2	4	4	6	8	12
1,000,000	0	0	1	3	3	3	3

Density of population. — By the density of population we usually mean the number of persons dwelling upon a unit area of land, as a square mile or an acre. It is not to be supposed that the persons within this unit area are uniformly distributed over it. Usually they are not. The ratio is one of convenience, however, and variations of density within the area under consideration are tacitly assumed. On the catchment area of the Croton river (331 square miles) which supplied New York with unfiltered water the population in 1903 was on an average about 52 per square mile, while on the catchment areas of many German streams, where the water is filtered before being used the population per square mile is often 500 or 800. Thus the average density expressed in this way is a valuable means of comparing the relative liability of the water to be contaminated, even though both in Germany and on the Croton catchment area the population consists of villages and farms irregularly scattered.

The average density of the population of the United States is steadily increasing. In 1790 it was only 4.5 persons per square mile; in 1860 it was 10.6; in 1910, 30.9; in 1920, 35.5 per square mile. The density varies greatly in the different states. Rhode Island has the greatest density. In 1920 it was 566.4 per square mile, Massachusetts came next with 479.2, then New Jersey with 420.0; Connecticut, 286.4; New York, 217.9; Pennsylvania, 194.5; Maryland, 145.8; Ohio, 141.4; Illinois, 115.7; and Delaware, 103.5. These were the only states above 100 per square mile. In Nevada the density was only 0.7 per square mile.

The density of population of the United States by counties in 1910 is shown in Fig. 34. The census of 1920 showed only slight changes.

When we need to know the variations in density more accurately we take a smaller unit of area. For the purpose

Thirteenth Census of the United States 1910.　Department of Commerce, Bureau of the Census

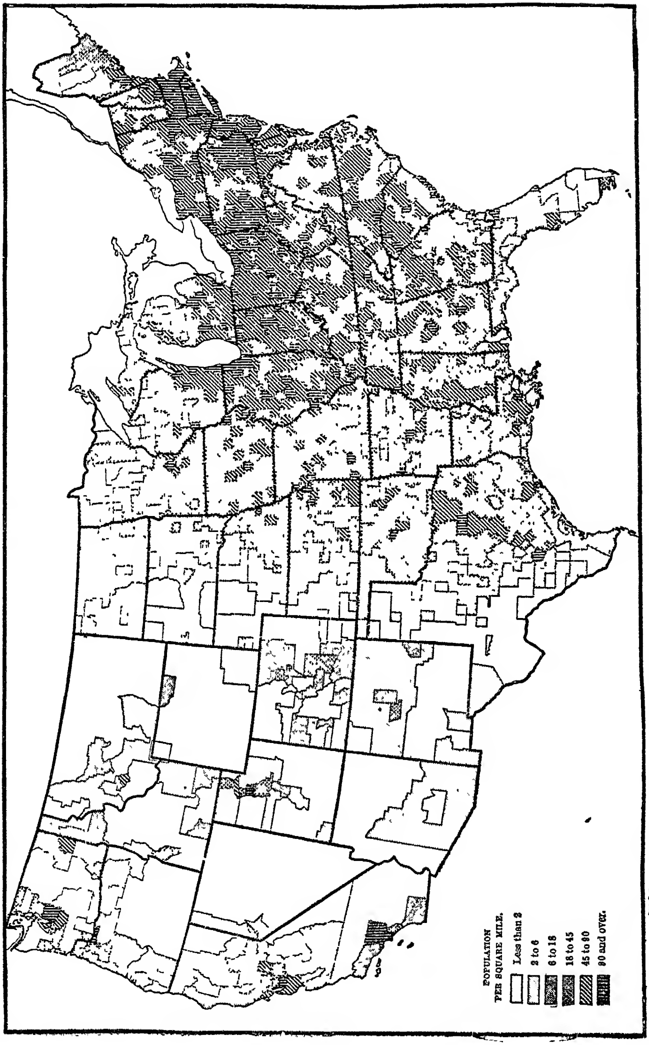


FIG. 34. — Population per Square Mile, by Counties: 1910.

of calculating the size of sewers required in a district, or for studying the congestion of population in a city the density per acre is computed. The population density in cities usually increases with their population. In the congested portions of cities the density may be several hundred per acre, sometimes over a thousand. Fig. 35 shows the densities of population in the different wards of Boston and Cambridge in the year 1910.

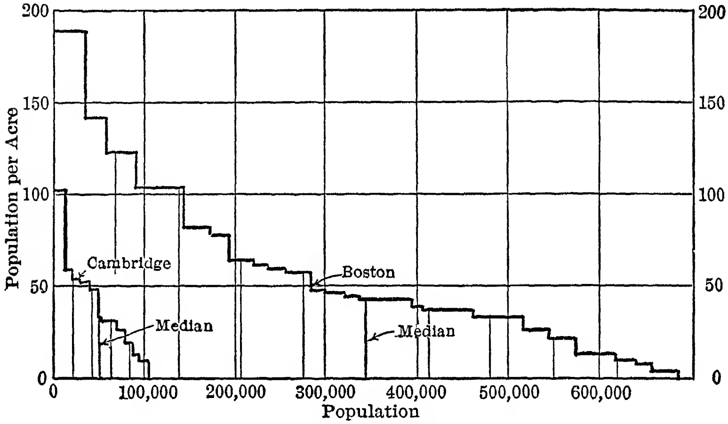


FIG. 35. — Density of Population by Wards in Boston and Cambridge, Mass.: 1910.

There are two ways in which the density of population of a city may be computed. The first and most common way is to divide the population by the area in acres. This gives the average density per acre. In Boston, for example, in 1910 the population was 670,585, the acreage, 27,674, and the number of persons on the average acre was 23.2. But if we place the people in array in accordance with the density of population of the ward where they reside we find that the median person lives where the density is about 50 per acre and that 10 per cent of the population live where the density is 125 per acre, 5 per cent where it is 150. In Cambridge, Mass., the average density per acre is 25.1, or practically the same as in Boston. The density for the median person is also about the same, *i.e.*, 50 per acre; but 10 per cent of the population live where it is more than 60 per acre, and only 5 per cent where it is 100. In no ward of Cambridge is the density as great as in five large populous wards of Boston.

For some purposes, such as designing a sewerage system, the average density per acre is what is wanted, but when we are considering the crowded condition of the people it is the median density based on population which is needed, and the proportion of people living under conditions of different congestion. We need also to consider areas as small as single blocks.

Population of United States Cities. — The figures in Table 26 will be found useful in computing vital rates. They are based on published reports of the U. S. Bureau of the Census.

TABLE 26

POPULATION OF UNITED STATES CITIES HAVING, IN 1920, 25,000 INHABITANTS OR MORE

	1900.	1910.	1920.
(1)	(2)	(3)	(4)
Alabama			
Birmingham	38,415	132,685	178,270
Mobile	38,469	51,521	60,151
Montgomery	30,346	38,136	43,464
Arizona			
Phoenix	5,544	11,134	29,053
Arkansas			
Fort Smith	11,587	23,975	28,811
Little Rock	38,307	45,941	64,997
California			
Alameda	16,464	23,383	28,806
Berkeley	13,214	40,434	55,886
Fresno	12,470	24,892	44,616
Long Beach	2,252	17,809	55,593
Los Angeles	102,479	319,198	576,673
Oakland	66,960	150,174	216,361
Pasadena	9,117	30,291	45,354
Sacramento	29,282	44,696	65,857
San Diego	17,700	39,578	74,683
San Francisco	342,782	416,912	508,410
San José	21,500	28,946	39,604
Stockton	17,506	23,253	40,296
Colorado			
Colorado Springs	21,085	29,078	30,105
Denver	33,859	213,381	256,369
Pueblo	28,157	44,395	42,908
Connecticut			
Bridgeport	70,996	102,054	143,538
Hartford	79,850	98,915	138,036
Meriden (town)	28,695	32,066	34,739
Meriden (city)	24,296	27,265	29,842
New Britain	25,998	43,916	59,316
New Haven	108,027	133,605	162,519
New London	17,548	19,659	25,688
Norwalk	6,125	6,954	27,743
Norwich (town)	24,637	28,219	29,685
Stamford (town)	18,839	28,836	40,057
Stamford (city)	15,997	25,138	35,086
Waterbury	45,859	73,141	91,410

TABLE 26

POPULATION OF UNITED STATES CITIES HAVING, IN 1920, 25,000 INHABITANTS OR MORE — (*Continued*)

	1900.	1910	1920.
(1)	(2)	(3)	(4)
Delaware			
Wilmington	76,508	87,411	110,168
District of Columbia			
Washington....	278,718	331,069	437,571
Florida			
Jacksonville . . .	28,429	57,699	91,558
Miami	1,681	5,471	29,549
Pensacola .. .	17,747	22,982	31,035
Tampa	15,839	37,782	51,252
Georgia			
Atlanta.. .. .	89,872	154,839	200,616
Augusta	39,441	41,040	52,548
Columbus . .	17,614	20,554	31,125
Macon	23,272	40,665	52,995
Savannah..........	54,244	65,064	83,252
Illinois			
Aurora . .	24,147	29,807	36,397
Bloomington .	23,286	25,768	28,725
Chicago	1,698,575	2,185,283	2,701,705
Cicero (town).	16,310	14,557	44,995
Danville. .. .	16,354	27,871	33,750
Decatur	20,754	31,140	43,818
East St. Louis.	29,655	58,547	66,740
Elgin....	22,433	25,976	27,454
Evanston..... .	19,259	24,978	37,215
Joliet. . . .	29,353	34,670	38,406
Moline . ..	17,248	24,199	30,709
Oak Park Village..		19,444	39,830
Peoria	56,100	66,950	76,121
Quincy.........	36,252	36,587	35,978
Rock Island	19,493	24,335	35,177
Rockford . .	31,051	45,401	65,651
Springfield....	34,159	51,678	59,183
Indiana			
Anderson	20,178	22,476	29,767
East Chicago.	3,411	19,098	35,967
Evansville.	59,077	69,647	85,264
Fort Wayne...	45,115	63,933	86,549
Gary	..	16,802	55,378
Hammond..... . . .	12,376	20,925	36,004

TABLE 26

POPULATION OF UNITED STATES CITIES HAVING, IN 1920, 25,000 INHABITANTS OR MORE — (*Continued*)

	1900	1910.	1920.
(1)	(2)	(3)	(4)
Indiana — (Continued)			
Indianapolis	169,164	233,650	314,194
Kokomo	10,609	17,010	30,067
Muncie	20,942	24,005	36,524
Richmond	18,226	22,324	26,765
South Bend	35,999	53,684	70,983
Terre Haute	36,673	58,157	66,083
Iowa			
Cedar Rapids	25,656	32,811	45,566
Clinton	22,698	25,577	24,151
Council Bluffs	25,802	29,292	36,162
Davenport	35,254	43,028	56,727
Des Moines	62,139	86,368	126,468
Dubuque	36,297	38,494	39,141
Sioux City	33,111	47,828	71,227
Waterloo	12,580	26,693	36,230
Kansas			
Kansas City	51,418	82,331	101,177
Topeka	33,608	43,684	50,022
Wichita	24,671	52,450	72,128
Kentucky			
Covington	42,938	53,270	57,121
Lexington	26,369	35,099	41,534
Louisville	204,731	223,928	234,891
Newport	28,301	30,309	29,317
Louisiana			
New Orleans	287,104	339,075	387,219
Shreveport	16,013	28,015	43,874
Maine			
Bangor	21,850	24,803	25,978
Lewiston	23,761	26,247	31,791
Portland	50,145	58,571	69,272
Maryland			
Baltimore	508,957	558,485	733,826
Cumberland	17,128	21,839	29,837
Hagerstown	13,591	16,507	28,066
Massachusetts			
Boston	560,892	670,585	748,060
Brockton	40,063	56,878	66,138
Brookline (town)	19,935	27,792	37,748

TABLE 26

POPULATION OF UNITED STATES CITIES HAVING, IN 1920, 25,000 INHABITANTS OR MORE — *(Continued)*

	1900.	1910.	1920.
(1)	(2)	(3)	(4)
Massachusetts — (Continued)			
Cambridge	91,886	104,839	109,694
Chelsea	34,072	32,452	43,184
Chicopee	19,167	25,401	36,214
Everett	24,336	33,484	40,120
Fall River	104,863	119,295	120,485
Fitchburg	31,531	37,826	41,013
Haverhill	37,175	44,115	53,884
Holyoke	45,712	57,730	60,203
Lawrence	62,559	85,892	94,270
Lowell	94,969	106,294	112,759
Lynn	68,513	89,336	99,148
Malden	33,664	40,404	40,103
Medford	18,244	23,150	39,038
New Bedford	62,442	96,652	121,217
Newton	33,587	39,806	46,054
Pittsfield	21,766	32,121	41,751
Quincy	23,899	3 ,642	47,876
Revere	10,395	18,219	28,823
Salem	35,956	43,697	42,529
Somerville	61,643	77,236	93,091
Springfield	62,059	88,926	129,563
Taunton	31,036	34,259	37,137
Waltham	23,481	27,834	30,915
Worcester	118,421	145,986	179,754
Michigan			
Battle Creek	18,563	25,267	36,164
Bay City	27,628	45,166	47,554
Detroit	285,704	465,766	993,739
Flint	13,103	38,550	91,599
Grand Rapids	87,565	112,571	137,634
Hamtramck Village		3,559	48,615
Highland Park	427	4,120	46,499
Jackson	25,180	31,433	48,374
Kalamazoo	24,404	39,437	48,858
Lansing)	16,485	31,229	57,327
Muskegon	20,818	24,062	36,570
Pontiac	9,769	14,532	34,273
Port Huron	19,158	18,863	25,944
Saginaw	42,345	50,510	61,903

TABLE 26

POPULATION OF UNITED STATES CITIES HAVING, IN 1920, 25,000 INHABITANTS OR MORE — (*Continued*)

	1900	1910	1920.
(1)	(2)	(3)	(4)
Minnesota			
Duluth	52,969	78,466	98,917
Minneapolis	202,718	301,408	380,582
St. Paul	163,065	214,744	234,595
Missouri			
Joplin	26,023	32,073	29,855
Kansas City	163,752	248,381	324,410
St. Joseph	102,979	77,403	77,939
St. Louis	575,238	687,029	772,897
Springfield	23,267	35,201	39,631
Montana			
Butte	30,470	39,165	41,611
Nebraska			
Lincoln	40,169	43,973	54,934
Omaha	102,555	124,096	191,601
South Omaha	26,001	26,259	. ..
New Hampshire			
Manchester	56,987	70,063	78,384
Nashua	23,898	26,005	28,379
New Jersey			
Atlantic City	27,838	46,150	50,682
Bayonne	32,722	55,545	76,754
Camden	75,935	94,538	116,309
Clifton	5,351	11,869	26,470
East Orange	21,506	34,371	50,710
Elizabeth	52,130	73,409	95,682
Hoboken	59,364	70,324	68,166
Irvington (town)	5,255	11,877	25,480
Jersey City	206,433	267,779	297,864
Kearny	10,896	18,659	26,724
Montclair	13,962	21,550	28,810
New Brunswick	20,006	23,388	32,779
Newark	246,070	347,469	414,216
Orange	24,141	29,630	33,268
Passaic	27,777	54,773	63,824
Paterson	105,171	125,600	135,866
Perth Amboy	17,699	32,121	41,707
Plainfield	15,369	20,550	27,700
Trenton	73,307	96,815	119,289
West Hoboken (town)	23,094	35,403	40,068

TABLE 26

POPULATION OF UNITED STATES CITIES HAVING, IN 1920, 25,000 INHABITANTS OR MORE — (*Continued*)

	1900.	1910.	1920.
(1)	(2)	(3)	(4)
New Jersey — (Continued)			
West New York (town)	5,267	13,560	29,926
New York			
Albany	94,151	100,253	113,344
Amsterdam	20,929	31,267	33,524
Auburn	30,345	34,668	36,192
Binghamton	39,647	48,443	66,800
Buffalo	352,387	423,715	506,775
Elmira	35,672	37,176	45,305
Jamestown	22,892	31,297	38,917
Kingston	24,535	25,908	26,688
Mount Vernon	21,288	30,919	42,726
New Rochelle	14,720	28,867	36,213
New York	3,437,202	4,766,883	5,621,151
Manhattan Borough	1,850,093	2,331,542	2,284,103
Bronx Borough	200,507	430,980	732,016
Brooklyn Borough	1,166,582	1,634,351	2,022,262
Queens Borough	152,999	284,041	466,811
Richmond Borough	67,021	85,969	115,959
Newburgh	24,943	27,805	30,366
Niagara Falls	19,457	30,445	50,760
Poughkeepsie	24,029	27,936	35,000
Rochester	162,608	218,149	295,750
Rome	15,343	20,497	26,341
Schenectady	31,682	72,826	88,723
Syracuse	108,374	137,249	171,717
Troy	60,651	76,813	72,013
Utica	56,383	74,419	94,156
Watertown	21,696	26,730	31,285
Yonkers	47,931	79,803	100,226
North Carolina			
Ashville	14,694	18,762	28,504
Charlotte	18,091	34,014	46,338
Wilmington	20,976	25,748	33,372
Winston-Salem	13,650	22,700	48,395
Ohio			
Akron	42,728	69,067	208,435
Canton	30,667	50,217	87,091
Cincinnati	325,902	363,591	401,247
Cleveland	381,768	560,663	796,836

TABLE 26

POPULATION OF UNITED STATES CITIES HAVING, IN 1920, 25,000 INHABITANTS OR MORE — *(Continued)*

	1900	1910.	1920.
(1)	(2)	(3)	(4)
Ohio — (Continued)			
Columbus	125,560	181,511	237,031
Dayton	85,333	116,577	152,559
East Cleveland	2,757	9,179	27,292
Hamilton	23,914	35,279	39,675
Lakewood	3,355	15,181	41,732
Lima	21,723	30,508	41,306
Lorain	16,028	28,883	37,295
Mansfield	17,640	20,768	27,824
Marion	11,862	18,232	27,891
Newark	18,157	25,404	26,718
Portsmouth	17,870	23,481	33,011
Springfield	38,253	46,921	60,840
Steubenville	14,349	22,391	28,508
Toledo	131,822	168,497	243,109
Warren	8,529	11,081	27,050
Youngstown	44,885	79,066	132,358
Zanesville	23,538	28,026	29,569
Oklahoma			
Muskogee	4,254	25,278	30,277
Oklahoma City	10,037	64,205	91,258
Tulsa	1,390	18,182	72,075
Oregon			
Portland	90,426	207,214	258,288
Pennsylvania			
Allentown	35,416	51,913	73,502
Altoona	38,973	52,127	60,331
Bethlehem	10,758	12,837	50,358
Chester	33,988	38,537	58,030
Easton	25,238	28,523	33,813
Erie	52,733	66,525	93,372
Harrisburg	50,167	64,186	75,917
Hazleton	14,230	25,452	32,277
Johnstown	35,936	55,482	67,327
Lancaster	41,459	47,227	53,150
McKeesport	34,227	42,694	45,975
Newcastle	28,339	36,280	44,938
Norristown (borough)	22,265	27,875	32,319
Philadelphia	1,293,697	1,549,008	1,823,158
Pittsburgh	451,512	533,905	588,193

TABLE 26

POPULATION OF UNITED STATES CITIES HAVING, IN 1920, 25,000 INHABITANTS OR MORE — *(Continued)*

	1900.	1910.	1920.
(1)	(2)	(3)	(4)
Pennsylvania — (Continued)			
Reading	78,961	96,071	107,784
Scranton	102,026	129,867	137,783
Shenandoah (borough)	20,321	25,774	24,726
Wilkes-Barre	51,721	67,105	73,833
Williamsport	28,757	31,860	36,198
York	33,708	44,750	47,512
Rhode Island			
Cranston	13,343	21,707	29,407
Newport	22,441	27,149	30,255
Pawtucket	39,231	51,622	64,248
Providence	175,597	224,326	237,595
Warwick (town)	21,316	26,629	13,481
West Warwick	......	......	15,461
Woonsocket	28,204	38,125	43,496
South Carolina			
Charleston	55,807	58,833	67,957
Columbia	21,108	26,319	37,524
South Dakota			
Sioux Falls	10,266	14,094	25,176
Tennessee			
Chattanooga	30,154	44,604	57,895
Knoxville	32,637	36,346	77,818
Memphis	102,320	131,105	162,351
Nashville	80,865	110,364	118,342
Texas			
Austin	22,258	29,860	34,876
Beaumont	9,427	20,640	40,422
Dallas	42,638	92,104	158,976
El Paso	15,906	39,279	77,543
Fort Worth	26,688	73,312	106,482
Galveston	37,789	36,981	44,255
Houston	44,633	78,800	138,076
San Antonio	53,321	96,614	161,379
Waco	20,686	26,425	38,500
Wichita Falls	2,480	8,200	40,079
Utah			
Ogden	16,313	25,580	32,804
Salt Lake City	53,531	92,777	118,110
Virginia			
Lynchburg	18,891	29,494	29,956

TABLE 26

POPULATION OF UNITED STATES CITIES HAVING, IN 1920, 25,000 INHABITANTS OR MORE — *(Concluded)*

	1900	1910.	1920.
(1)	(2)	(3)	(4)
Virginia — (Continued)			
Newport News	19,635	20,205	35,596
Norfolk	46,624	67,452	115,777
Petersburg	21,810	24,127	31,002
Portsmouth	17,427	33,190	54,387
Richmond	85,050	127,628	171,667
Roanoke	21,495	34,874	50,842
Washington			
Bellingham	11,062	24,298	25,570
Everett	7,838	24,814	27,644
Seattle	80,671	237,194	315,652
Spokane	36,848	104,402	104,437
Tacoma	37,714	83,743	96,965
West Virginia			
Charleston	11,099	22,996	39,608
Clarksburg	4,050	9,201	27,869
Huntington	11,923	31,161	50,177
Wheeling	38,878	41,641	54,322
Wisconsin			
Green Bay	18,684	25,236	31,017
Kenosha	11,606	21,371	40,472
La Crosse	28,895	30,417	30,363
Madison	19,164	25,531	38,378
Milwaukee	285,315	373,857	457,147
Oshkosh	28,284	33,062	33,162
Racine	29,102	38,002	58,593
Sheboygan	22,962	26,398	30,955
Superior	31,091	40,384	39,624

Metropolitan districts. — For some purposes the population of a city plus its adjacent suburbs of more importance than that of the city itself. During recent years the growth of the suburbs has often been much greater than that of the city itself. This subject is discussed in U. S. Census, 1920, Vol. I, p. 62.

In 1920, New York City had a population of 5,620,048, the adjacent territory, 2,290,367, or 41 per cent of the city's population. During the last decade the city increased 17.9 per cent and the adjacent territory 27.2 per cent.

In Boston, 1920, the city's population was 748,060, that of the adjacent territory, 1,024,194, or 137 per cent of the city's population.

Classification of population. — One of the greatest mistakes which health officers make is failure to take into account the make-up of the population. Two places cannot be fairly compared as to death-rate or birth-rate, unless the composition of the population in the places is substantially the same. This point will be emphasized again in Chapter VIII.

In many demographic studies it is necessary to take into account age, sex, and nationality as primary factors; and at times also such matters as marital condition, school attendance, illiteracy, ownership of homes, occupation, and so on.

It will not be possible in this volume to go into all of these classifications. They should be carefully studied, however, from the census reports themselves. Every health officer should know the composition of the people in the city or district under his jurisdiction.

Color or race, nativity and parentage. — The racial composition of the United States has changed materially in fifty years. This is well illustrated by Fig. 36. In 1850 about three-quarters of the people were native whites, now only about one-half. There are great differences in different cities and states.

TABLE

POPULATION OF CITIES HAVING, IN 1920,

	CITY	POPU-				
		1920	1910	1900	1890	1880
1	New York, N Y.[1]	5,620,048	4,766,883	3,437,202	2,507,414	1,911,698
2	Manhattan borough	2,284,103	2,331,542	1,850,093	1,441,216	1,164,673
3	Bronx borough	732,016	430,980	200,507	88,908	51,980
4	Brooklyn borough	2,018,356	1,634,351	1,166,582	838,547	599,495
5	Queens borough	469,042	284,041	152,999	87,050	56,559
6	Richmond borough	116,531	85,969	67,021	51,693	38,991
7	Chicago, Ill	2,701,705	2,185,283	1,698,575	1,099,850	503,185
8	Philadelphia, Pa.	1,823,779	1,549,008	1,293,697	1,046,964	847,170
9	Detroit, Mich.	993,678	465,766	285,704	205,876	116,340
10	Cleveland, Ohio	796,841	560,663	381,768	261,353	160,146
11	St. Louis, Mo	772,897	687,029	575,238	451,770	350,518
12	Boston, Mass [2]	748,060	670,585	560,892	448,477	362,839
13	Baltimore, Md	733,826	558,485	508,957	434,439	332,313
14	Pittsburgh, Pa [3]	588,343	533,905	451,512	343,904	235,071
15	Los Angeles, Calif.	576,673	319,198	102,479	50,395	11,183
16	Buffalo, N. Y	506,775	423,715	352,387	255,664	155,134
17	San Francisco, Calif.	506,676	416,912	342,782	298,997	233,959
18	Milwaukee, Wis.	457,147	373,857	285,315	204,468	115,587
19	Washington, D. C.[5]	437,571	331,069	278,718	230,392	177,624
20	Newark, N. J.	414,524	347,469	246,070	181,830	136,508
21	Cincinnati, Ohio	401,247	363,591	325,902	296,908	255,139
22	New Orleans, La.	387,219	339,075	287,104	242,039	216,090
23	Minneapolis, Minn.	380,582	301,408	202,718	164,738	46,887
24	Kansas City, Mo.	324,410	248,381	163,752	132,716	55,785
25	Seattle, Wash.	315,312	237,194	80,671	42,837	3,533
26	Indianapolis, Ind.	314,194	233,650	169,164	105,436	75,056
27	Jersey City, N. J.	298,103	267,779	206,433	163,003	120,722
28	Rochester, N. Y.	295,750	218,149	162,608	133,896	89,366
29	Portland, Oreg.	258,288	207,214	90,426	46,385	17,577
30	Denver, Colo.	256,491	213,381	133,859	106,713	35,629
31	Toledo, Ohio	243,164	168,497	131,822	81,434	50,137
32	Providence, R. I.	237,595	224,326	175,597	132,146	104,857
33	Columbus, Ohio	237,031	181,511	125,560	88,150	51,647
34	Louisville, Ky.	234,891	223,928	204,731	161,129	123,758
35	St. Paul, Minn.	234,698	214,744	163,065	133,156	41,473
36	Oakland, Calif.	216,261	150,174	66,960	48,682	34,555
37	Akron, Ohio	208,435	69,067	42,728	27,601	16,512
38	Atlanta, Ga.	200,616	154,839	89,872	65,533	37,409
39	Omaha, Nebr.[6]	191,601	124,096	102,555	140,452	30,518
40	Worcester, Mass	179,754	145,986	118,421	84,655	58,291
41	Birmingham, Ala.	178,806	132,685	38,415	26,178	3,086

27

100,000 INHABITANTS OR MORE, 1790-1920

LATION

1870	1860	1850	1840	1830	1820	1810	1800	1790	
1,478,103	1,174,779	696,115	391,114	242,278	152,056	119,734	79,216	49,401	1
942,292	813,669	515,547	312,710	202,589	123,706	96,373	60,515	33,131	2
37,393	23,593	8,032	5,346	3,023	2,782	2,267	1,755	1,781	3
419,921	279,122	138,882	47,613	20,535	11,187	8,303	5,740	4,495	4
45,468	32,903	18,593	14,480	9,049	8,246	7,444	6,642	6,159	5
33,029	25,492	15,061	10,965	7,082	6,135	5,347	4,564	3,835	6
298,977	109,260	29,963	4,470		. .	.			7
674,022	565,529	121,376	93,665	80,462	63,802	53,722	41,220	28,522	8
79,577	45,619	21,019	9,102	2,222	1,422	.		. .	9
92,829	43,417	17,034	6,071	1,076	606	. .			10
310,864	160,773	77,860	16,469		. . .	. .			11
250,526	177,840	136,881	93,383	61,392	43,298	33,787	24,937	18,320	12
267,354	212,418	169,054	102,313	80,620	62,738	46,555	26,514	13,503	13
139,256	77,923	67,863	31,204	15,369	7,248	4,768	1,565		14
5,728	4,385	1,610		.	.				15
117,714	81,129	42,261	18,213	8,668	2,095				16
149,473	56,802	[4]34,776		. . . .	. . .				17
71,440	45,246	20,061	1,712	.	.				18
109,199	61,122	40,001	23,364	18,826	13,247	8,208			19
105,059	71,941	38,894	17,290		. . .			.	20
216,239	161,044	115,435	46,338	24,831	9,642	2,540		. . .	21
191,418	168,675	116,375	102,193	46,082	27,176	17,242	. . . .	. . . . . .	22
13,066	2,564	. . . .	. .		. .	. .	. . . .	. . . . .	23
32,260	4,418	. .	.	.		.	. . .	. . . . .	24
1,107	.	.				.		. . . .	25
48,244	18,611	8,091	2,692			.	. .	. . . . . .	26
82,546	29,226	6,856	3,072			.	. . .	.	27
62,386	48,204	36,403	20,191	9,207			.		28
8,293	2,874								29
4,759									30
31,584	13,768	3,829	1,222				.		31
68,904	50,660	41,513	23,171	16,833	11,767	10,071	7,614	6,380	32
31,274	18,554	17,882	6,048	2,435			.	.	33
100,753	68,033	43,194	21,210	10,341	4,012	1,357	359	200	34
20,030	10,401	1,112	.		.			.	35
10,500	1,543				. . . . . .			.	36
10,006	3,477	3,266			. . . .				37
21,789	9,554	2,572	.		. . . .				38
16,083	1,883		.	.	. . . . .				39
41,105	24,960	17,049	7,497	4,173	2,962	2,577	2,411	2,095	40
. . . . .		. .							41

TABLE

POPULATION OF CITIES HAVING, IN 1920,

	CITY	POPU-				
		1920	1910	1900	1890	1880
42	Syracuse, N Y.	171,717	137,249	108,374	88,143	51,792
43	Richmond, Va	171,667	127,628	85,050	81,388	63,600
44	New Haven, Conn.	162,537	133,605	108,027	81,298	[7] 62,882
45	Memphis, Tenn.	162,351	131,105	102,320	64,495	33,592
46	San Antonio, Tex.	161,379	96,614	53,321	37,673	20,550
47	Dallas, Tex.	158,976	92,104	42,638	38,067	10,358
48	Dayton, Ohio	152,559	116,577	85,333	61,220	38,678
49	Bridgeport, Conn.	143,555	102,054	70,996	48,866	27,643
50	Houston, Tex	138,276	78,800	44,633	27,557	16,513
51	Hartford, Conn.	138,036	98,915	79,850	53,230	42,015
52	Scranton, Pa.	137,783	129,867	102,026	75,215	45,850
53	Grand Rapids, Mich.	137,634	112,571	87,565	60,278	32,016
54	Paterson, N. J.	135,875	125,600	105,171	78,347	51,031
55	Youngstown, Ohio	132,358	79,066	44,885	33,220	15,435
56	Springfield, Mass.	129,614	88,926	62,059	44,179	33,340
57	Des Moines, Iowa	126,468	86,368	62,139	50,093	22,408
58	New Bedford, Mass.	121,217	96,652	62,442	40,733	26,845
59	Fall River, Mass.	120,485	119,295	104,863	74,398	48,961
60	Trenton, N. J.	119,289	96,815	73,307	57,458	29,910
61	Nashville, Tenn.	118,342	110,364	80,865	76,168	43,350
62	Salt Lake City, Utah	118,110	92,777	53,531	44,843	20,768
63	Camden, N J.	116,309	94,538	75,935	58,313	41,659
64	Norfolk, Va.	115,777	67,452	46,624	34,871	21,966
65	Albany, N. Y.	113,344	100,253	94,151	94,923	90,758
66	Lowell, Mass.	112,759	106,294	94,969	77,696	59,475
67	Wilmington, Del.	110,168	87,411	76,508	61,431	42,478
68	Cambridge, Mass.	109,694	104,839	91,886	70,028	52,669
69	Reading, Pa.	107,784	96,071	78,961	58,661	43,278
70	Fort Worth, Tex.	106,482	73,312	26,688	23,076	6,663
71	Spokane, Wash.	104,437	104,402	36,848	19,922	. . .
72	Kansas City, Kans.	101,177	82,331	51,418	38,316	3,200
73	Yonkers, N. Y.	100,176	79,803	47,931	32,033	18,892

[1] Population shown is for New York and its boroughs as now constituted.

[2] Hyde Park town annexed to Boston city since 1910. Combined population· 1910, 686,092; 1900, 574,136; 1890, 458,670; 1880, 369,927, 1870, 254,662. Hyde Park not returned separately at earlier censuses.

[3] Includes population of Allegheny, as follows: 1900, 129,896; 1890, 105,287; 1880, 78,682; 1870, 53,180; 1860, 28,702; 1850, 21,262, 1840, 10,089; and 1830, 2,801. Allegheny not returned separately at earlier censuses.

[4] Population as reported by state census of 1852; returns for 1850 for San Francisco were destroyed by fire.

27 — (*Continued*)

100,000 INHABITANTS, OR MORE 1790-1920

LATION

1870	1860	1850	1840	1830	1820	1810	1800	1790	
43,051	28,119	22,271							42
51,038	37,910	27,570	20,153	16,060	12,067	9,735	5,737	3,761	43
[7] 50,840	[7] 39,267	[7] 20,345	12,960	10,180	7,147	5,772	4,049		44
40,226	22,623	8,841							45
12,256	8,235	3,488							46
									47
30,473	20,081	10,977	6,067	2,950	1,000	383			48
18,969	[7] 13,299	[7] 7,560	3,294						49
9,382	4,845	2,396							50
37,180	[7] 29,152	[7] 17,966	9,468	7,074	4,726	3,955			51
35,092	9,223								52
16,507	8,085	2,686							53
33,579	19,586								54
8,075	2,759	2,802							55
26,703	15,199	11,766	10,985	6,784	3,914	2,767	2,312	1,574	56
12,035	3,965								57
21,320	22,300	16,443	12,087	7,592	3,947	5,651	4,361	3,313	58
26,766	14,026	11,524	6,738	4,158	1,594	1,296			59
22,874	17,228	6,461	4,035	3,925	3,942	3,002			60
25,865	16,988	10,165	6,929	5,566					61
12,854	8,236								62
20,045	14,358	9,479	3,371						63
19,229	14,620	14,326	10,920	9,814	8,478	9,193	6,926	2,959	64
69,422	62,367	50,763	33,721	24,209	12,630	10,762	5,349	3,498	65
40,928	36,827	33,383	20,796	6,474					66
30,841	21,258	13,979	8,367						67
39,634	26,060	15,215	8,409	6,072	3,295	2,323	2,453	2,115	68
33,930	23,162	15,743	8,410	5,856	4,332	([8])	2,386		69
									70
									71
									72
									73

[5] Population as returned from 1880 to 1920 is for District of Columbia, with which city is now coextensive.

[6] Omaha and South Omaha cities consolidated since 1910. Combined population: 1910, 150,355; 1900, 128,556; 1890, 148,514. South Omaha not returned separately at earlier censuses.

[7] Population of town, including city; town and city not returned separately.

[8] Not returned separately.

[9] Less than one-tenth of 1 per cent.

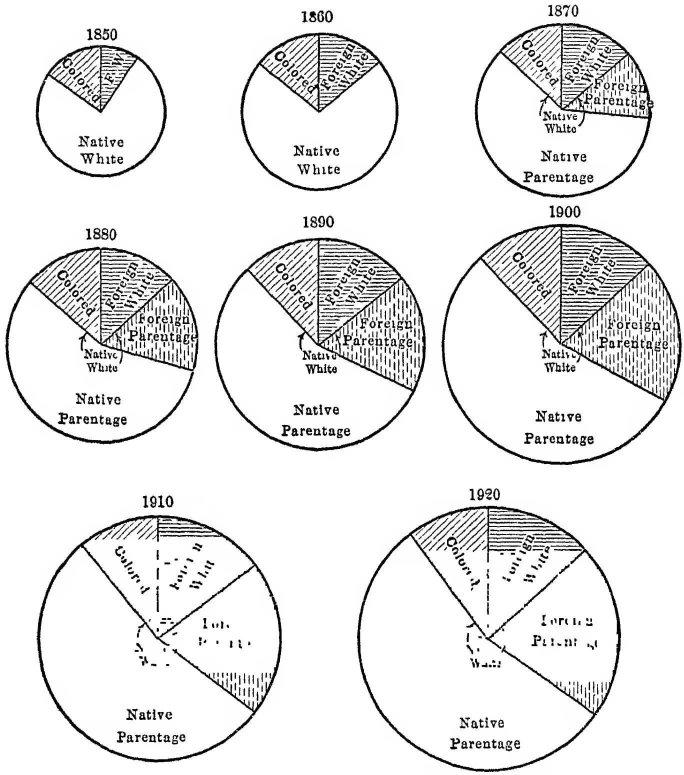


Fig. 36.—Racial Composition of Population of the United States.

According to the U. S. Bureau of the Census the population is divided into six classes: (1) white, (2) negro, (3) Indian, (4) Chinese, (5) Japanese and (6) "all others." The white population is subdivided into:

a. Native, native parentage, having both parents born in the United States.
b. Native, foreign parentage, having both parents born in foreign countries.
c. Native, mixed parentage, having one native parent and the other foreign born.
d. Foreign born.

It is often desirable to subdivide the foreign born according to the country from which they came. This is true also of the parents. The composition of the population has an important influence on birth-rates, sickness-rates and death-rates, hence it is a subject which should be carefully studied by every health officer. It is too complicated to be discussed in detail in an elementary book.

Sex distribution. — There are two ways in which the sexes are compared, — one is to compute the percentage which the number of each sex is of the total population, the other is to compute the ratio of males to females. Thus, we have the following figures for 1920:

TABLE 28

COMPARISON OF SEXES IN THE UNITED STATES

United States.	Per cent.		Males to 100 females.
	Male	Female	
(1)	(2)	(3)	(4)
Total population	51.0	49.0	104 0
Native white, native parentage .	50 7	49 3	103 0
Native white, mixed parentage . .	49 3	50.7	97 7
Native white, foreign parentage	49.8	50 2	99 1
Foreign born white	54 8	45.2	121.7

In most parts of the country males are in excess, and generally speaking the ratio of males to females increases from east to west. In only a few states do we find females in excess. One of these is Massachusetts, where in 1920 the ratio was only 96.3. In Nevada, on the other hand, the ratio was 148.5, not very far from two men to one woman.

Sex distribution ought to be studied in connection with age distribution.

Dwellings and families. — A knowledge of the number of persons in a dwelling or a family is of sociological interest, and it may be of practical use in estimating the population of an area the boundaries of which are not coincident with any civil division. Here we come again to the difficulty of definition. What is a dwelling? What is a family? A dwelling-house is considered to be " a place where one or more persons regularly sleep." An apartment house, although the abiding place of many families, constitutes but one " dwelling." A family is " a household or group of persons who live together, usually sharing the same table." This includes both private families, consisting of persons related by blood, and economic families.

The ideal family has been said to consist of a father and mother and three children with an occasional grandfather or grandmother, aunt or uncle. In the United States in 1920 the average number of persons to a family was only 4.3, — apparently much smaller than the ideal. The average number of persons to a dwelling was 5.1. Figures for different parts of the country are given in Table 29.

For housing problems it is not enough to know that the average number of persons per dwelling is 5.1. This extra tenth of a person is difficult to place. We need to know how many dwellings contain one person, how many two persons, and how many three, four, five, six, and so on. It is difficult to secure these data.

TABLE 29

SIZE OF FAMILIES AND HOUSEHOLDS, 1920

Place	Persons per dwelling	Persons per family	Families per dwelling.
(1)	(2)	(3)	(4)
United States	5 1	4.3	1 21
Urban*	5 9	4 5	1.31
Rural*	4 7	4 6	1 02
New England	5 9	4 4	1.34
Urban*	6 5	4 6	1.41
Rural*	4 2	4 0	1.05
New York City	15 3	4 4	3 48
Borough of Manhattan	30.3	4.4	6.98
Boston	9 4	4 5	2 09
Cambridge, Mass.	7 1	4 2	1.69
Los Angeles, Cal.	4.6	3.6	1 28
Spokane, Wash.	4.7	3 8	1.23

* Census of 1910.

The shortage of houses since the war is seen in the facts that in 1920 in the United States there were 1.21 families per dwelling while in 1910 there were only 1.15 families per dwelling.

Age distribution. — We now come to what is a most important division of the population, namely separation into age-groups. In connection with a study of death-rates and causes of death a knowledge of age distribution is fundamental. As a factor in vital statistics it is more important than sex or nationality or parentage or occupation or any other particular characteristic.

In taking a census it is impossible to find the exact age of every person in a community, and even if this could be done it would be impracticable to arrange the people in groups, varying by short intervals of time. Infants and young children may be grouped by their age in weeks or months, but older persons are seldom divided into groups for which the time interval is less than one year. Five-year and ten-year groups are even more commonly used. In this chapter we shall not consider smaller subdivisions than one year. The ages of infants will be taken up in the chapter which treats of infant mortality.

Census meaning of age. — If we wish to state a person's age in years, using a whole number, we may do so in one of two ways; we may give the age as that of the *last birthday* or as that of the *nearest birthday.* The difference is by no means insignificant in the case of children, for the difference of half a year would represent a large percentage of the age. In some parts of the world the *next birthday* is often stated as the age, an infant being regarded as one year of age even though he had been born only an hour. In the Orient age has to do also with the calendar year in which the child was born. A child born in November might in December be called a year old, but after January first might be called two years. These curious customs ought to be known by those enumerating the ages of persons in the foreign quarters of our cities and justify the check question asked by census enumerators, namely, the *date of birth.*

The *last birthday* method was used in the United States census of 1920, 1910, 1900 and 1880; it is the method used in England. In 1890, however, the *nearest birthday* was used. The effect of the definition of age on the age-grouping will be apparent from Fig. **37**. The nearest birthday method creates

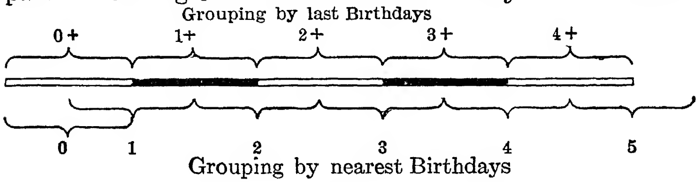


FIG. 37. — Age-Grouping by Years.

confusion in the ages of infants and children one year old. If infants include children up to the age of one year, then the "one-year" group must be limited to half a year or else there is confusion of those between six months and one year. The discrepancies in the 1890 figures are plainly shown by the following table which gives the percentage distribution of the population under five years of age.

TABLE 30

PER CENT DISTRIBUTION OF POPULATION UNDER 5 YEARS OF AGE

Age in years	"Nearest birthday."	"Last birthday."			
	1890	1880	1900	1910.	1920.
(1)	(2)	(3)	(4)	(5)	(6)
	Per cent.	Per cent	Per cent.	Per cent.	Per cent.
Under 1 year	20.5	20 9	20 9	20 9	19.5
1 +	14 1	18 2	19 3	18.6	....
2 +	22 7	20 6	20.0	20.4	. .
3 +	21 4	20 0	19 9	20.3	....
4 +	21 3	20 3	20.0	19 9	. ..
Total under 5 years	100.0	100 0	100 0	100.0	100.0

The small number in the one-year group and the large number in the two-year group in 1890 should be noticed.

Errors in ages of children. — The above table shows that even by the last-birthday method the age distribution of children in one-year groups was unsatisfactory. Normally there are more children under one year of age than between one and two years, more between one and two than between two and three and more between three and four than between four and five. Yet in 1910 the one-year group contained fewer than the two-year group, and in 1900 the 3+ year group contained fewer than the 4+ year group.

These discrepancies are due to errors. They are greatest in populations where there is much illiteracy and where no attempt is made to check the age returns by asking the date of birth. Thus we may compare the data for Germany (1900) and the negro population of the United States (1910).

TABLE 31

PERCENTAGE DISTRIBUTION OF POPULATION UNDER 5 YEARS

Age.	Germany.	United States (Negro population.)
(1)	(2)	(3)
0+	20 6	20 0
1+	20 3	17 4
2+	20 2	20 6
3+	19 5	20 9
4+	19 3	21.1
Under 5	100 0	100.0

Errors due to use of round numbers. — An important source of error in age statistics is that of mixing round numbers with more accurate figures. In replying to the enumerator's questions concerning age most persons will state their age accurately, but some will give the nearest round number. An ignorant or careless person who may be 39 or 41 years old may give his age as 40, a figure which in his mind is near enough. This habit is encouraged by ask-

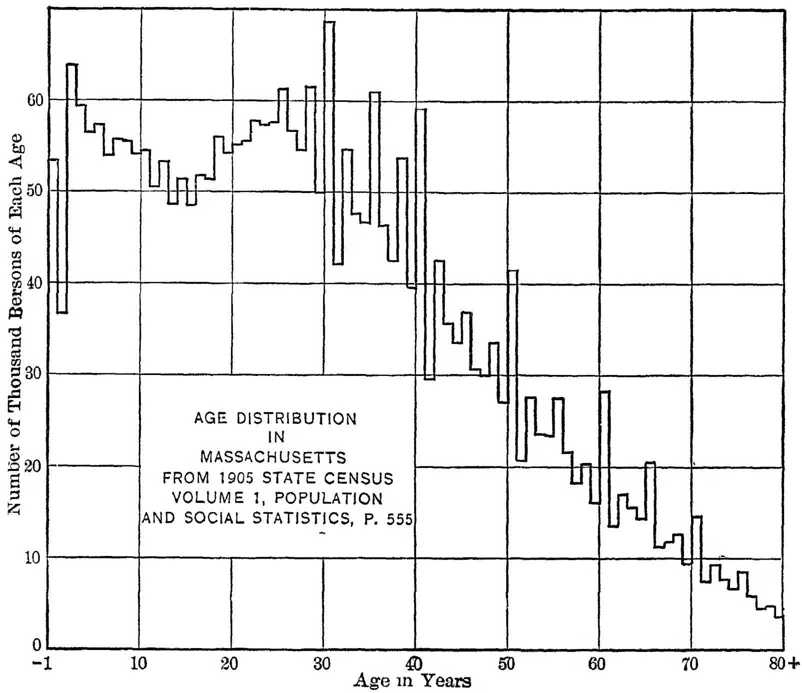


Fig. 38. — Age Distribution in Massachusetts.

ing for the " nearest birthday " as was done in 1890. In most censuses there are enough instances of this sort to produce noticeable concentrations around the ages ending in 0 or 5. This is well illustrated by Fig. 38, which shows the population of Massachusetts males in 1905 distributed by groups. This error of round numbers is by no means confined to the subject of age. It is met with in all sorts of statistical work. Dates are often stated as "the first of the month," or the tenth or the fifteenth. These, mixed with more accurate statements, may produce abnormal concentrations. Methods of adjusting data troubled with these concentrations on the round numbers are used by statisticians and may be found in technical books on statistics.

The U. S. Census Bureau in studying the error due to the abnormal use of round numbers has made use of a measure termed the "Index of Concentration." This was taken to be the "per cent which the number reported as multiples of 5 forms of one-fifth of the total number between ages 23 to 62 years, inclusive." Thus in the U. S. in 1910 there were 43 million persons aged 23 to 62 years. One-fifth of these would be 8.6 million. The total number of persons aged 23 to 62 whose age was reported as a multiple of 5 was 10.3 million. Hence the index of concentration was 10.3 ÷ 8.6 = 1.20, or an index of 120.

TABLE 32

ERRORS OF REPORTING AGE

Country.	Date.	Index of concentration.
(1)	(2)	(3)
Belgium	1900	100
England and Wales	1901	100
Sweden	1900	101
German Empire	1900	102
France	1901	106
Canada	1881	110
Hungary	1900	133
Russian Empire	1897	182
Bulgaria	1905	245

It was found that the index of concentration increased directly with the ignorance and illiteracy. For the native white persons it was 112; for foreign born whites, 129; for colored persons, 153. It is interesting to compare these figures for those of certain other countries.

Other sources of error. — Besides ignorance as to age there are other sources of error. One of these is deliberate under-estimate of age, most conspicuous among middle-aged women. Another is over-estimate, most conspicuous among the aged. The latter is of relatively little weight, but the former tends to overload the early ages of adult life.

Age groups. — The primary tabulations of the census give the ages of the people by single years. For practical use and for application to particular localities it is necessary to combine them into groups of five, ten, or twenty years, or other groups suitable to particular needs. There appears to be no recognized standard of age grouping, and perhaps this is not desirable as there are many different uses to which the figures are put.

The U. S. Census states the boundaries of the groups in inclusive numbers, such as 0–4; 5–9; 10–14; etc., and not in round numbers, as 0–5; 5–10; 10–15. With the original age records given in years it is undoubtedly the most exact method.

A condensed grouping used in the 1920 census was the following:

Under 5 Years
(Under 1 Year)
5–9
10–14
15–19
20–24
25–34
35–44
45 and over
Age unknown

Sometimes there are one-year groups from ages one to five, 5-year groups from ages five to twenty-five, 10-year groups from twenty-five to forty-five, and above that twenty-year groups.

The International Congress which met in Paris in October, 1920, proposed the following age grouping with the two sexes listed separately:

From 0 to 1 year
From 1 to 19 years
From 20 to 39 years
From 40 to 59 years
From 60 to

and suggested that where possible the second group should be subdivided thus:

From 1 to 4 years
From 5 to 14 years
From 15 to 19 years

The advisability of using the same age-grouping for population records as for records of deaths and sickness was strongly emphasized.

Persons of unknown age. — One of the puzzling things about age distribution is to know how to treat the "age unknown." Usually this number is not large, but in particular cases it may be. In 1920 only 0.14 per cent of the people of the United States were included in this group, in 1910, 0.18 per cent, and in 1900, 0.26 per cent.

One way is to place them in a group by themselves, letting the size of the group stand as a sort of test of the accuracy of the investigation. On the whole this is probably the best thing to do.

Another way would be to distribute the unknowns pro rata through the other groups. But there is really no justification for doing so, because the persons of unknown age may be confined to certain selected ages, as the very old.

Redistribution of population. — If the ages of the people are tabulated by years it is of course easy to combine them into any desired age-groups; but if the data are tabulated according to one age-grouping and it is desired to ascertain the numbers in other age-groups the problem is more difficult. Approximate results only can be expected and these can be obtained by graphical methods or by computation.

For this purpose the summation diagram is most convenient.

In 1910 the population of Cambridge was as follows:

TABLE 33

POPULATION OF CAMBRIDGE, MASS., BY AGE-GROUPS

Age-group.	Number.	Age.	Persons less than stated age	
			Number.	Per cent
(1)	(2)	(3)	(4)	(5)
0–1	2,323	1	2,323	2 3
1–4	8,479	5	10,802	10 4
5–9	9,471	10	20,273	19 4
10–14	8,892	15	29,165	27 9
15–19	8,930	20	37,095	36 4
20–24	10,408	25	47,503	46.4
25–34	19,175	35	66,678	64 6
35–44	15,726	45	82,404	79.6
45–64	16,732	65	99,136	95 6
65–99	4,642	100	104,778	99.4
Unknown	61	.	61	0.6
Total	104,839	....	104,839	100.0

The figures in column (4) are plotted in Fig. 39. Let us suppose that we desire to obtain the number of persons in age-group 23–27 inclusive. The diagram shows that about 43,500 were less than 23 years old and about 53,500 less than 28 years old. The group, therefore, contains 53,500 − 43,500, or 10,000.

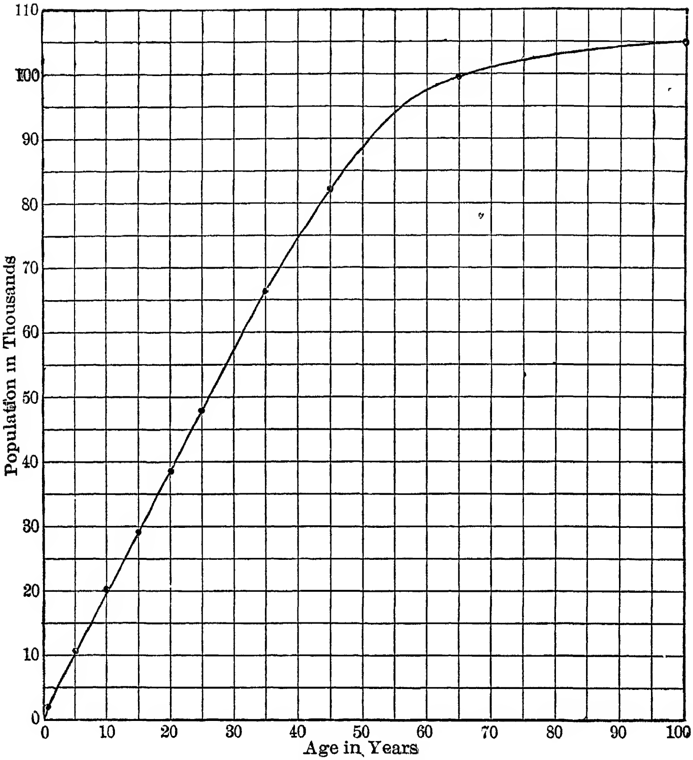


FIG. 39. — Age Distribution of Population shown by Summation Curve, Cambridge, Mass.: 1910.

In making a complete redistribution of the population in new age-groups it is well to check the results by adding them together to see that they equal the total. The accuracy of the result will depend upon the scale used for plotting and the smoothness of the curve.

We might compute the number of persons in age-group 23–27 as follows:

$$
\begin{aligned}
10{,}408 \times \tfrac{2}{5} &= 4163 \\
19{,}175 \times \tfrac{3}{10} &= \underline{5753} \\
& 9916
\end{aligned}
$$

This assumes a uniform age distribution within each age-group, which is not strictly correct.

Redistribution of population for non-censal years. — In the case of non-censal years the method of redistribution of population is essentially the same as that just described but there are three steps to the process.

The first step is to estimate the total population for the year in question by methods already described.

The second step is to find the percentage distribution of the population as it was at the time of the nearest census. As a rule the percentage composition of a population by age-groups does not change rapidly from year to year. For an intercensal year it would be possible to find the percentage distribution for both the preceding and following census and by interpolation obtain more accurate percentages for the intercensal years. The use of the summation curve is the most convenient method however.

The third step is to multiply the estimated total population by the percentages obtained in the second step. The feature of this problem obviously lies in the second step.

Let us try to find the age distribution of the population of Cambridge in the year 1906. In addition to the above figures for 1910 we have also from the census records the following figures for 1900, plotted in Fig. 40.

TABLE 34

ESTIMATES OF POPULATION BY AGE-GROUPS FOR A NON-CENSAL YEAR: CAMBRIDGE, MASS.

Age-group.	Number.	Age	Persons less than stated age.	
			Number.	Per cent.
(1)	(2)	(3)	(4)	(5)
0-1	2,123	1	2,123	2 3
1-4	7,519	5	9,642	10 5
5-9	8,343	10	17,985	19 6
10-14	7,331	15	25,316	27 5
15-19	7,781	20	33,097	36 0
20-24	10,588	25	43,685	47 5
25-29	9,973	30	53,658	58 4
30-34	8,157	35	61,815	67 3
35-44	12,377	45	74,192	78 5
45-54	8,561	55	82,753	90 0
55-64	5,028	65	87,781	95 5
65-99	3,652	100	91,433	99 4
Unknown	453		453	.....
Total	91,886	....	91,886	... .

The percentage distribution for 1900 and 1910 are both shown on Fig. 40. It will be noticed that the two curves coincide for the upper and lower ages, but not for the middle ages. For the year 1906 the percentages to be used would naturally lie somewhere between the two.

Progressive character of age distribution. — Among the causes of the variation of death-rates from year to year is the progressive change in age distribution. We often overlook this. We know that individuals grow old, but we forget that the 10 year old children of today will be 20 years old ten years hence, and 30 years old ten years later and so on. We are less wise than the motley fool who said:

> "It is ten o'clock:
> 'Tis but an hour ago since it was nine,
> And after one hour more 'twill be eleven;
> And so from hour to hour, we ripe and ripe,
> And then, from hour to hour, we rot and rot;
> And thereby hangs a tale."

While the age distribution of a population does not change rapidly from year to year yet it does change. This is strikingly shown by the statistics of Sweden from 1750 to 1900. During this interval there was but little emigration or immi-

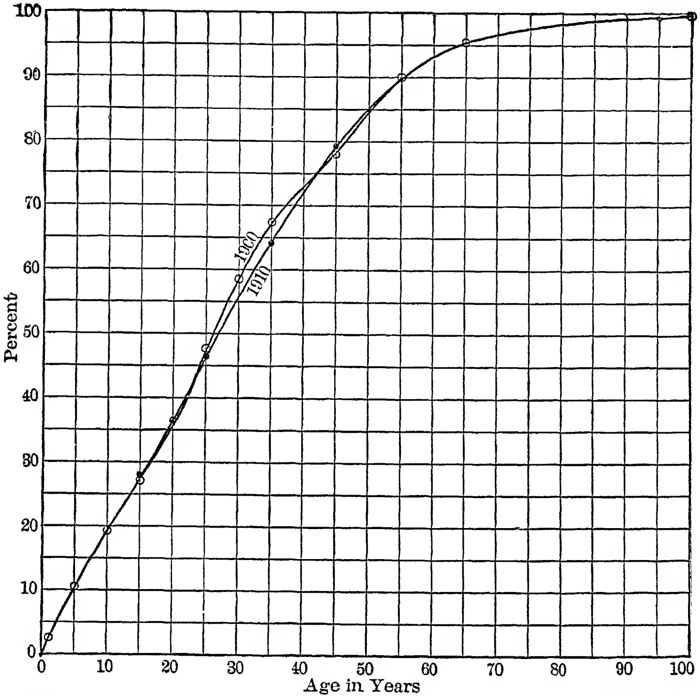


FIG. 40. — Percentage Age Distribution of Population, Cambridge, Mass., showing slight differences in ten years.

gration, but the birth-rate varied considerably. In Fig. 40, the population data are plotted for five-year groups and for five-year intervals of time; consequently the persons who appeared in the 0–4-group at one date would appear in the 5–9-group five years later, except as losses by death occurred.

It is interesting to see how the influences which increase or decrease the numbers of children produce results which flow as waves throughout a long life-term. For example, the high birth-rate between 1820 and 1825, which caused a peak

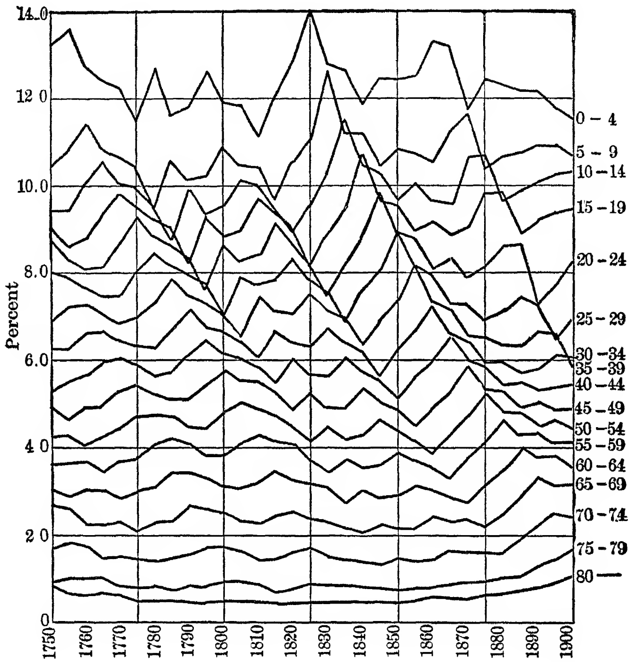


FIG. 41. — Age Distribution of the People of Sweden by Five-Year Groups: 1750–1900.

in the 0–4-group in 1825, caused a peak in the 5–9-group in 1830 and this could be traced for three-score years and ten. In the same way the trough in the 0–4 curve in 1810 can be followed for sixty years.

This same progressive change in age distribution can be observed in Massachusetts in spite of the fact that the curves are confused by accessions due to immigration. The peak in the 0–4-group in 1860 can be followed for fifteen years, but after that immigration appears to control. The immigration peak seen in the 20–24-group in 1880 can likewise be traced almost to 1910.

This progressive change of age is very important, for with constant specific death-rates for each age it would automatically control the general death-rate. It shows too that a loss of millions of young men in the present Great War will profoundly affect the age distribution of the nations of Europe for half a century to come. There is much food for reflection in this study.

Types of age distribution. — According to Sundbärg one of the striking features of normal age distribution is the fact that about one-half of the population are between 15 and 50 years of age. He distinguishes three types of age distribution. The first is the *Progressive Type*, the second the *Stationary Type*, and the third, the *Regressive Type*. These are illustrated by the following typical groupings:

TABLE 35

TYPES OF POPULATION

Age-group, years.	Per cent of population		
	Progressive type	Stationary type.	Regressive type.
(1)	(2)	(3)	(4)
0–14	40	33	20
15–49	50	50	50
50–	10	17	30

It will be noticed that in all cases, the proportion of middle-aged persons is the same, and that the classification depends upon the proportion of persons under 15 years of age to those more than 50 years of age.

To these classes might be added two more, one in which a population has lost many of its middle-aged persons by emigration and one in which a population has gained by accessions of middle-aged persons. If the percentage of persons between 15 and 50 years of age is much less than 50 it indicates that the place has lost by emigration and this may be termed the *secessive type;* while if the percentage of persons between 15 and 50 years of age is greater than 50 it may be termed the *accessive type.*

The following are examples of age distribution on the basis of this classification:

TABLE 36

TYPES OF POPULATION BASED ON AGE-GROUPING

	Per cent of population.		
	0–14 years.	15–49 years.	50 years and over.
(1)	(2)	(3)	(4)
Sweden (1751–1900)	33	50	17
United States (1910)	32	54	15
Massachusetts	27	57	16
Minnesota	32	54	14
New York State	27	58	15
Washington State	26	61	13
Maine	27	51	22
Mass., native white of native parentage	28	50	22
Mass., native white of foreign or mixed parentage	46	48	6
Mass., foreign-born white	6	74	20

It will be seen that Sweden has a normal stationary population, Massachusetts has an accessive population with 57 per cent between 15 and 50 years. Washington is even more accessive. Maine tends to be regressive, as it has an abnormally large number of persons over 50 years of age. This is also the case with the population of native-white parentage of Massachusetts. The native-white population of foreign or mixed parentage, however, is decidedly progressive.

Ratio of deaths to births. — The usefulness of the percentage ratio of deaths to births in the study of population movement has been pointed out by Dr. Raymond Pearl,[1] Professor of Biometry and Vital Statistics in the School of Hygiene and Public Health, Johns Hopkins University, who has given an interesting comparison between the United States, England, France, and the City of Vienna during the Great War. The figures are as follows: —

TABLE 37

NUMBER OF DEATHS PER 100 BIRTHS

Year.	U S. birth registration area.	England and Wales.	France, (77 non-invaded departments)	Vienna.
1912	......	56	.. .	80
1913	.....	57	97	85
1914	.. ...	59	110	86
1915	56	69	169	113
1916	59	65	193	143
1917	57	75	179	195
1918	73[1]	92	198	229
1919	58	73	. ...	162

[1] Effect of influenza epidemic.

Standards of age distribution. — For purposes of computation and comparison it is often convenient to have some standard of age distribution which can be used as a basis of reference. Several have been suggested.

A simple one was the actual population of Sweden in 1890.

[1] Science, N. S. LI, p. 553; also LIII, p. 120.

This was suggested because the country was not much influenced by emigration or immigration. This standard had only five groups. It was this:

TABLE 38

AGE DISTRIBUTION OF SWEDEN, 1890

Age-group.	Per cent.
(1)	(2)
0–1	2 55
1–19	39.80
20–39	26.96
40–59	19.23
60–	11 46
	100 00

The "Standard Million," namely the population of England and Wales in 1901, has been much used in adjusting birth-rates and death-rates. It is as follows:

TABLE 39

ENGLAND AND WALES STANDARD MILLION OF 1901

Age-group.	Males.	Females.	Persons.
(1)	(2)	(3)	(4)
0–4	57,039	57,223	114,262
5–9	53,462	53,747	107,209
10–14	51,370	51,365	102,735
15–19	49,420	50,376	99,796
20–24	45,273	50,673	95,946
25–34	76,425	85,154	161,579
35–44	59,394	63,455	122,849
45–54	42,924	46,298	89,222
55–64	27,913	31,828	59,741
65–74	14,691	18,389	33,080
75–	5,632	7,949	13,581

G. H. Knibbs and C. H. Wickens,[1] statisticians of the Commonwealth of Australia have worked out in a very elaborate way the probable normal age distribution of the people of Europe for the year 1900 or thereabouts. Eleven countries are considered. The results were as follows:

TABLE 40

PER CENT OF POPULATION AT EACH AGE

(Eleven Countries of Europe)

Age	Per cent.	Age	Per cent	Age	Per cent.	Age	Per cent	Age	Per cent.
(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
0	2 46	19	1 90	38	1 25	57	0 67	76	0 20
1	2 43	20	1 86	39	1 21	58	0 64	77	0 18
2	2 41	21	1 83	40	1 18	59	0 62	78	0 16
3	2 38	22	1 80	41	1 15	60	0 59	79	0 13
4	2 35	23	1 76	42	1 11	61	0 57	80	0 11
5	2 33	24	1 73	43	1 08	62	0 54	81	0 10
6	2 30	25	1 69	44	1 05	63	0 51	82	0 08
7	2 27	26	1 66	45	1 02	64	0 49	83	0.07
8	2 24	27	1 62	46	0 99	65	0 46	84	0 05
9	2 21	28	1 59	47	0 96	66	0 44	85	0.04
10	2 19	29	1 56	48	0 93	67	0 42	86	0 03
11	2 15	30	1 52	49	0 89	68	0 39	87	0 02
12	2 12	31	1 49	50	0 86	69	0 37	88	0 02
13	2 09	32	1 45	51	0 84	70	0 34	89	0.01
14	2 06	33	1 41	52	0 81	71	0 32	90	
15	2 03	34	1 38	53	0 78	72	0 29	91	
16	2 00	35	1 35	54	0 75	73	0 27	92	0 02
17	1 96	36	1 31	55	0 73	74	0 24	93	
18	1 93	37	1 28	56	0 70	75	0 22	94	
								All ages	100 0

Age distribution of the population of the United States. — On account of the heterogeneous character of the people of the United States, due to immigration and to internal

[1] The Determination and Uses of Population Norms representing the Constitution of Populations according to Age and Sex, and according to Age only, Transactions, 15th International Congress on Hygiene and Demography, Vol. VI, p. 352.

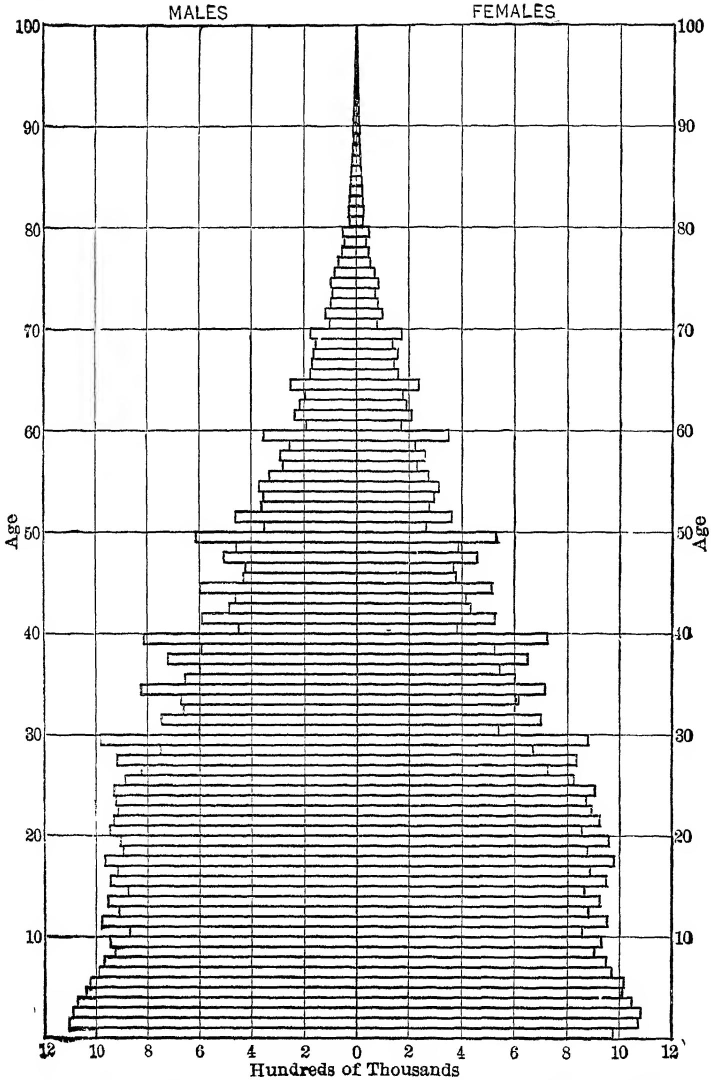


FIG. 42. — Distribution of Population by Age and Sex, United States, 1910.

migrations, we find that states and cities vary widely in the age composition of their inhabitants. In the older parts of the country we find a more normal age distribution of the people, one that approaches that of Sweden and Switzerland, but in the newer sections, especially in the west, we find an abnormally large number of persons of middle-age. This is also true of cities to which persons of middle-age are drawn. On the other hand the rural districts are relatively low in the middle-age groups. There are also important differences between native whites, foreign born whites and negroes; and between males and females. The student is urged to study in the census reports these differences among different classes of populations and in different sections of the country.

The following table shows the percentages of total population in 1910 arranged by years:

TABLE 41

PER CENT OF TOTAL POPULATION, BY SINGLE YEARS, 1910

(United States)

Age	0	10	20	30	40	50	60	70	80	90
0	2 4	2 0	2 0	2 0	1 7	1 2	0 7	0 4		
1	2 1	1 9	1 9	1 2	0 9	0 7	0 4	0 2		
2	2.4	2 1	2 0	1 6	1 2	0 9	0 5	0 2	0 3	*
3	2 3	1 9	1 9	1 4	1 0	0 7	0 4	0 2		
4	2 3	2 0	1 9	1 4	0 9	0 7	0 4	0 2		
5	2 2	1 9	2 0	1 7	1 2	0 7	0 5	0 2		
6	2 2	2.0	1 8	1 4	0 9	0 7	0 3	0 2		
7	2 1	1 9	1 7	1 2	0 9	0.5	0 3	0 1	0.1	†
8	2 1	2 1	1 9	1 5	1 0	0.6	0 3	0 1		
9	2.0	1.9	1 5	1 2	0.9	0 5	0 3	0 1		

* Less than 0.1%. † Age unknown = 0 2%

The concentrations around the years ending in 0 and 5 should be noticed. The differences between the percentages for males and females in the whole population are relatively slight.

Demographic view of population. — Local health officers seldom have occasion to consider the laws of population in a broad way, but a study of this subject is enlightening. There are two important principles that should be kept in mind. The first is that the use of natural resources makes larger populations possible, and the second is that higher standards of living tend to check the increase of population. We see these influences at work in the United States. Our resources are far from being exhausted, but the ratio of certain food products to population, say the animal foods, is not what it once was. On the basis of present food-supplies it is possible to predict an ultimate limit for our population, but who can say what the limit will be should the people of the United States gradually change to a food basis like that of China? The birth-rate among recent immigrants to the United States is commonly higher than that of the succeeding generation. The check of higher living standards is seen in operation. What will be the effect of these laws on Asia? Will not the development of resources in Siberia be a stimulus to population growth in that great country, a country not only abounding in natural wealth but with great possibilities for a high order of civilization? On the other hand, will not the development of diversified industries in China bring about higher standards of living and check the birth-rate, thus making China not larger but better?

G. H. Knibbs, in his stimulating book on "The Mathematical Theory of Population," has called attention to these great influences. He emphasizes not only the possession of natural resources, but the human knowledge and power to utilize them; he discusses the cosmic energies which facilitate man's development, and the various sociological forces which are at work. We study these things, we extend out population curves forward, and then we look at the ruins of Egypt, Babylon, Rome and Carthage, and wonder. In summing up his studies, Knibbs says, "The limits of human expansion are much nearer than popular opinion imagines: the present rate of increase in the world's population cannot continue for four centuries, and the extraordinary increase in the standards of living which has characterized the last few decades must quickly be brought to a standstill or be determined by the destructive forces of human extravagance. Very soon world-politics will have to face the question whether it is better that there should be larger numbers and more modest living or fewer numbers and lavish living."

Movement of population. — The term "movement of population," used commonly by European demographers, does not refer exclusively to migration, as one might naturally think, but includes those changes produced by births and deaths as well as those of emigration and immigration.

EXERCISES AND QUESTIONS

1. What were the points in the Washington controversy in regard to death-rates and population? [See Am. J. P. H., Apr., 1917, June, 1917, Feb., 1918.]

2. From the data given in Table 3, 13th Census, Population, Vol. I., p. 24, estimate by three methods the probable population of the United States in 1950.

3. What was the average annual percentage rate of increase of the population of the United States between 1790 and 1800, assuming a geometrical rate of increase? Between 1900 and 1910?

4. Under what temperature conditions do the people of the United States live? (See 11th Census, page ix.)

5. Under what rainfall conditions do the people of the United States live? (See 11th Census, page ix.)

6. From data given on page 314 of the 13th Census, Population, Vol. I, make a table giving the age distribution by single years of the entire population of the United States, the native white of native parentage and the foreign born white.

7. Make a plot of the last two.

8. Assuming the age distribution of the United States native white population of native parentage (both sexes) as given below, find by graphical methods the age distribution as indicated.

Given		Wanted	
Age	Per cent	Age	Per cent
0–4	13 2	0–4	?
5–9	11 8	5–14	?
10–19	21.1	15–24	?
20–29	17.7	25–34	?
30–39	13 1	35–44	?
40–49	9 2	45–64	?
50–59	6 9	65–84	?
60–69	4.4		
70–79	2 1		
80–89	0 5		

Check the result by computation from figures given in previous problems.

9. Look up the " Incremental Increase Method " of estimating future populations. (Jour. Am. Water Works Asso., March, 1915.)

10. What is meant by the "Center of Population?" Where was the centre of population in the United States in 1790? In 1910? [U. S. Census, 1910, Population, Vol. I, p. 45.]

11. What is the " median point "?

12. Which states have the largest per cents of urban population?

13. Describe Moore's "Expectancy Curve," for estimating future populations. (Engineering News, Nov. 2, 1916, p. 844.)

CHAPTER VI

PREDICTION OF FUTURE POPULATION

(Mr. Dana E. Kepner, Assistant in Sanitary Engineering, Harvard Engineering School, 1921-2, collaborated with the author in the preparation of this chapter.)

For many purposes it is necessary to make an estimate of what the population of a place will be ten, twenty, or perhaps fifty or more years in the future. City planning is fundamentally dependent upon such predictions. However much we may moralize and say, "No one can foretell what the future has in store for us," it is absolutely necessary to make population estimates as the basis of plans for water supply, sewerage systems and many other municipal works. In business it is desirable to know what the future population of cities and regions is likely to be. So, too, in political matters a knowledge of the future trend of the voting population is important.

Methods commonly used. — Estimates of future population are sometimes made by applying the principles of arithmetical or geometrical increase referred to on pages 141 and 142. These are not very reliable; the former generally gives too low results and the latter too high results. It is logical to extrapolate arithmetically using the last two census records, for a short period ahead, say ten years; but in estimating for longer periods it is necessary to base the prediction on longer historical records. This is a principle which applies to many things in life. The farther you look ahead the more you must look back. It means the use of experience. The public health student who desires to project himself forcibly into the coming years needs to study the history of the health of the human race and the methods which have been employed to protect it.

Graphical methods are more common and, on the whole, are more useful than these numerical computations.

The simplest method and one commonly used is to plot the past census records of population on ordinary cross-section paper and, using them as guides, project forward a line in continuation of the apparent trend of the plotted data. This is usually done by the eye, but sometimes by the use of the mathematical device known as "curve fittings." This method is very local and assumes the continuation of the conditions of growth which have controlled past increases in population. It has proved a useful method for short period estimates but has its shortcomings.

Another method, also commonly employed by engineers, is to secure data for older and larger communities, where the conditions are reasonably comparable; ascertain what their growth was after they had reached the size of the city being studied; and use these facts as guides in extending the population curve forward. This method, coupled with the first one, tends to strengthen confidence in the resulting prediction. It is open to this objection, however. The cities taken as comparates are larger than the city being studied because they have grown more rapidly. It follows, therefore, that the data often represent rates of growth too high to be used as reliable guides. This may be one reason why engineers' estimates of future population are so often too high.

A third method is to make use of all sorts of local data, which may influence future growth, — the density of population, the character of the industries, housing, transportation facilities, and so on. These are for the most part indirect, indefinite factors, yet they may be of very great importance, outweighing the refinements of curve-fitting and upsetting the smoothness of projected lines. These local factors, if used to modify the results of the first two methods, still further enhance confidence in the resulting prediction: but it usually requires some courage to apply them if they are at variance with the mathematical curves.

There is a fourth factor which is very rarely considered, — namely, the trend of population in large regions adjacent to the city in question, — and still a fifth, the general principles of population growth as developed from a study of the science of demography. The fundamental laws of population are biologic and economic, using these terms in a very broad sense. An understanding of some of the fundamental principles of population growth and a knowledge of the movement of population in the different countries and different parts of our own country are valuable guides in making estimates by the other three methods.

An example of the graphical method. — The following is an example of the graphical method of estimating population.

Estimate the future population of Springfield, Mass., using for comparison the cities of Worcester, Mass., Syracuse, N. Y., Rochester, N. Y., and Providence, R. I. From the census reports we have the following data:

TABLE 42

POPULATION OF CITIES

Year.	Springfield.	Worcester.	Syracuse.	Rochester.	Providence.
(1)	(2)	(3)	(4)	(5)	(6)
1860	15,199	24,960	28,119	48,204	50,666
1870	26,703	41,105	43,051	62,386	68,904
1880	33,340	58,291	51,792	89,366	104,857
1890	44,179	84,655	88,143	133,896	132,146
1900	62,059	118,421	108,374	162,608	175,597
1910	88,926	145,986	137,249	218,149	224,326

These data are first plotted as in the upper part of Fig. 43. They are afterwards brought together as in the lower part of the figure, the lines being made to cross on the line

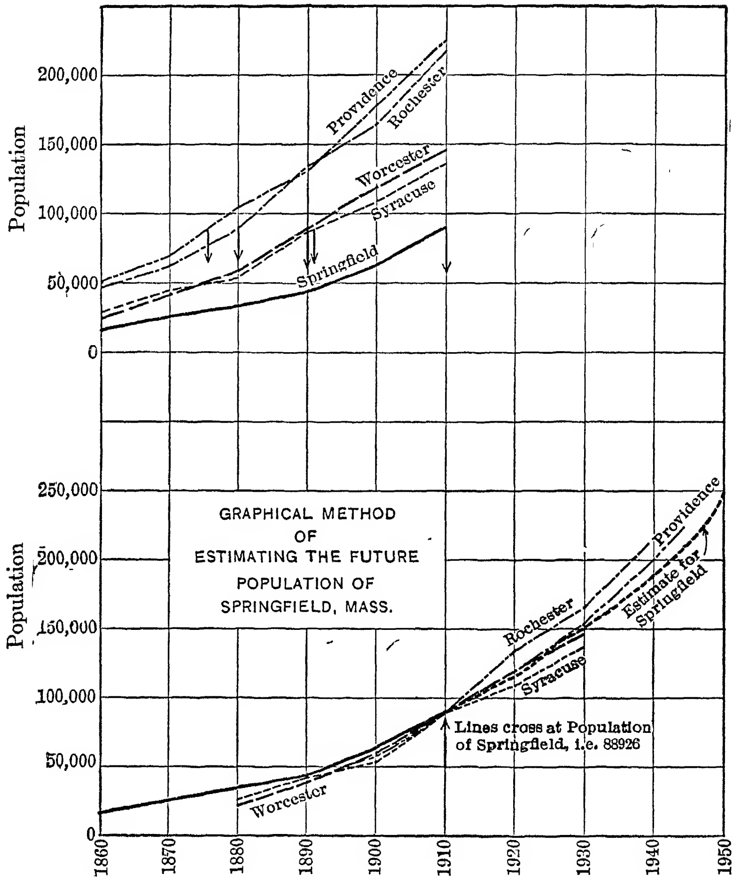


FIG. 43.—Example of Graphical Method of Estimating Future Population. (See also Fig. 46.)

of 1910. The estimate for Springfield is made by sweeping the curve forward as shown.

Best graphical method of estimating future population. — Recent studies have shown that the semi-log cross-section paper described on page 87 is much better than ordinary cross-section paper for estimating future population. Plotted on this paper a series of numbers which increase at a constant rate will make a straight line. Census figures may therefore be plotted and, if a straight line results, projected forward as a continued straight line. It will usually be found, however, that the census figures do not give a straight line but a curve sloping downward, indicating that the rate of growth is decreasing. The curve is often so regular that it can be projected forward as a continued curve. This, however, is merely the mathematical outline of the problem. Other factors need consideration, as described beyond.

As an example of this we may take cities and towns making up the present Boston Metropolitan Water District from 1850 to 1920 and plot the figures on semi-log paper, as in Fig. 44. It will be seen that they do not yield a straight line, but a downward sloping curve, which can be projected forward without much difficulty. As a further guide in projecting the line forward the five-year increments[1] may be plotted as shown in the figure and this line projected forward, the results being used to project forward the main curve.

Semi-log paper may also be used in the estimation of future populations when comparing the rate of growth of other cities and towns with that of the city in question. Thus, instead of using the direct plotting paper shown in Fig. 43, the semi-log paper, shown in Fig. 46, may be employed, remembering that steeper slopes mean higher rates of growth.

[1] In Massachusetts the census is taken once in five years.

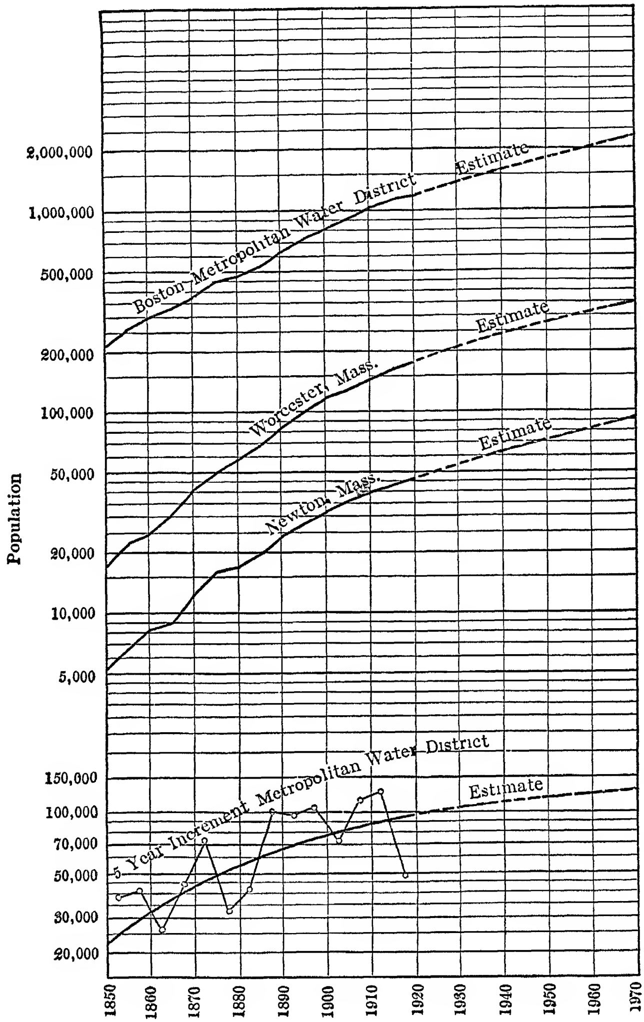


Fig. 44.—Estimates of Future Population by plotting on Semi-logarithmic paper.

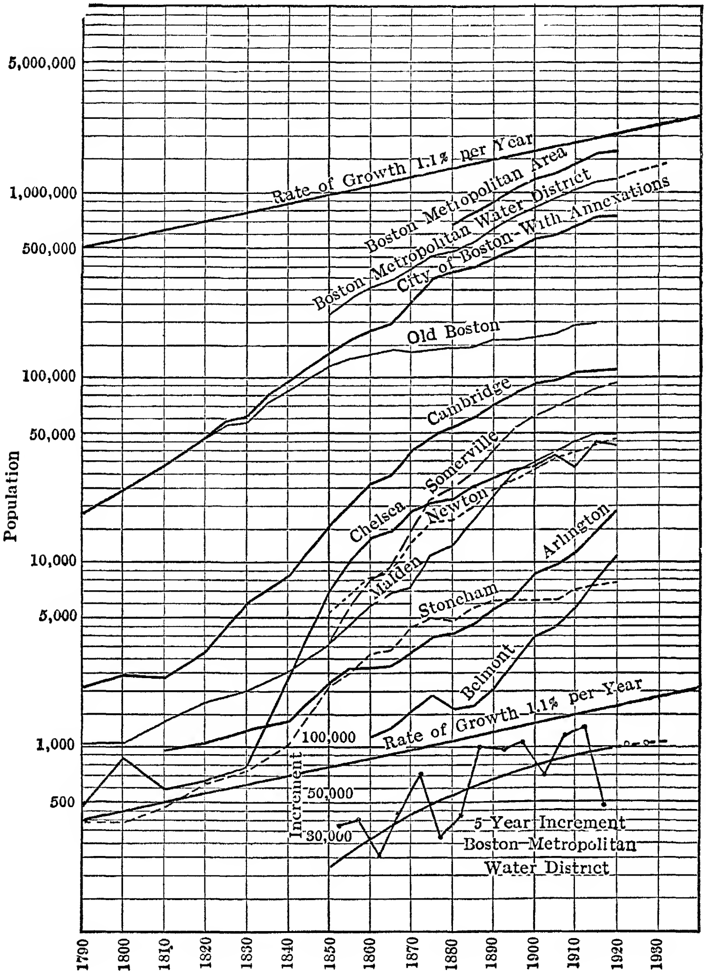


FIG. 45. — Population of Boston and Certain Neighboring Cities and Towns, plotted on Semi-logarithmic paper.

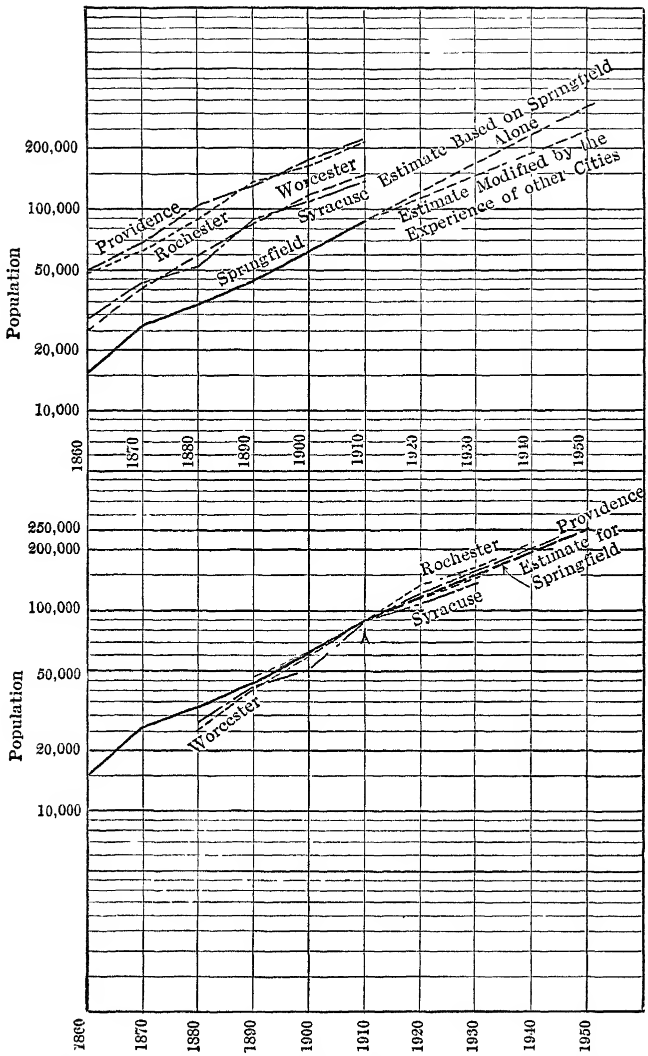


FIG. 46 —Example of Graphical Method of Estimating Future Population, using Semi-logarithmic Plotting Paper. (Compare with Fig. 43.)

World conditions. — Fundamentally the growth of population depends upon the excess of births over deaths and, looking at the population of the world during the last hundred years, it is surprising to find how constant the growth has been. Census records do not exist for all countries, but by putting together the data for the English speaking countries, the Teutonic countries, the Latin countries, and the Scandinavian countries we obtain figures which, when plotted on semi-log paper, fall very nearly on a straight line. In Fig. 47, Line B represents the aggregate populations of those countries for which there are records since 1800, — namely, Norway, Sweden, Denmark and Finland; England, Wales, Ireland, Scotland; Australia, the United States, France, and Germany. Line A includes the same countries plus Italy, Spain, Portugal, Austria, Belgium, Hungary, and Canada, for which there are data since 1860.

It will be seen from these lines that the aggregate population of those countries, which may be said to represent our Western Civilization, has increased since 1800 at the average rate of 1.1 per cent per year. There have been some variations from this average rate, but only between the limits of 0.91 and 1.28 per cent, while the ups and downs have just about balanced themselves. The point for 1910 was slightly above the line, due apparently to a spurt in the population of the German states and to the migration into the countries included in our list from those not included; but the point for 1920, some of the figures for which are not yet available, will probably be back on the line, if not slightly below it.

It is interesting to study the population lines of the different countries, shown in Figs. 47 and 48, for they not only reflect history but give a broad outlook on population movments. The populations have been plotted on semi-log paper in order that the relative rates of growth may be com-

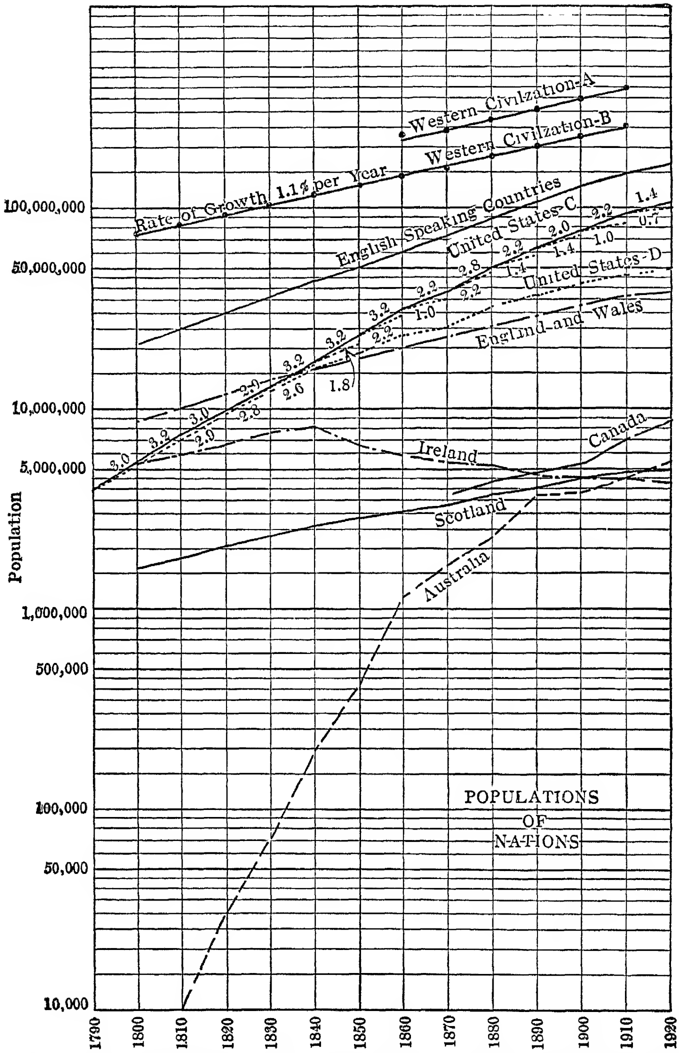


FIG. 47. — Populations of Certain Nations, 1790 to 1920, plotted on Semi-logarithmic paper.

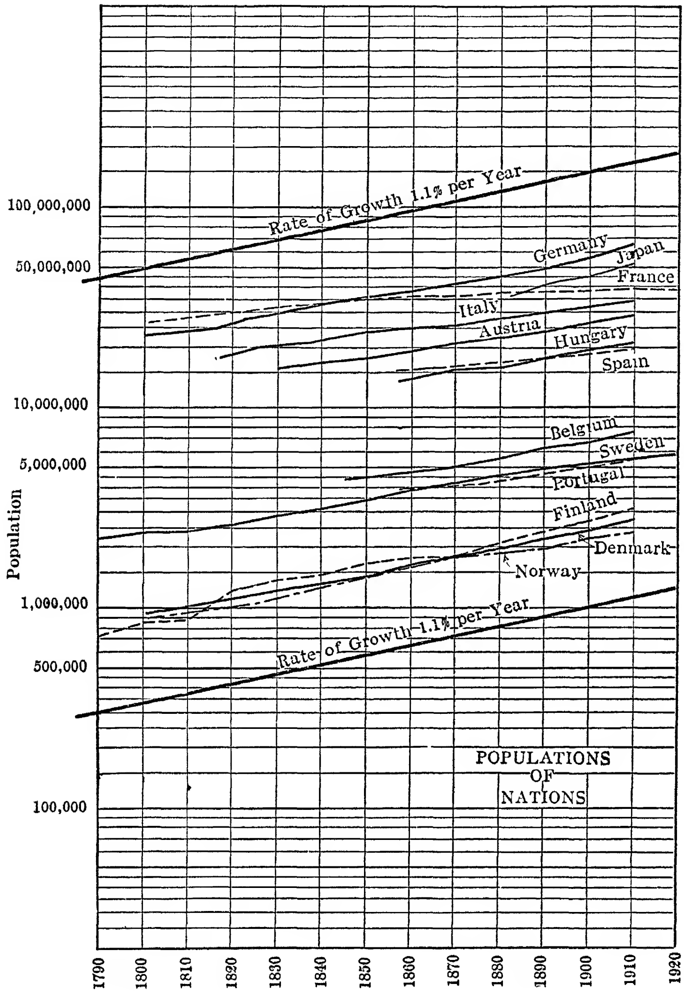


FIG. 48. — Population of Certain Nations plotted on Semi-logarithmic paper.

pared by observing the slopes of the lines. A straight line indicates a uniform rate. An easy way to measure the annual rate of increase is to draw on tracing-cloth, or better on a celluloid sheet, a slope diagram like that shown in Fig. 49, and slide it around over the diagrams being studied. This slope diagram has to be drawn, of course, for the particular scales used in the population diagrams.

The average rate of growth of England and Wales between 1801 and 1831 was 1.5 per cent per year. Then began the period of colonial expansion and from 1831 to 1911 the rate remained constant at 1.2 per cent. Between 1911 and 1921 it fell to 0.5 per cent. The rate for Scotland has not been as steady as for England and Wales, but has fallen from 1.2 per cent in the early eighties to 0.9 per cent just before the Great War. Between 1801 and 1841 Ireland was growing at a 1.1 per cent rate. Then came famine, emigration, and bad economic conditions which resulted in a great decrease in population. Between 1841 and 1851 the decrease in rate was 2.2 per cent per year, but between 1891 and 1911 only 0.3 per cent, and 1911 to 1921, 0.5 per cent. Although the population line has not reached the turning point (1921), the recent changes in government may result in an increase of population before many years. If the rate of growth which prevailed between 1801 and 1841 had continued, the population would now be more than twenty million, and even if the rate had decreased gradually, as in Scotland, it would be nearly fifteen million. One may speculate as to what would have happened in the Emerald Isle had these conditions prevailed. Australia grew at the rate of more than 9 per cent per year between 1821 and 1861, then the rate fell to about 3.5 per cent and later to 2.0 between 1911 and 1921. Canada had a 1.2 per cent growth between 1871 and 1901; 2.6 per cent between 1901 and 1911, and 2.0 per cent between 1911 and 1921.

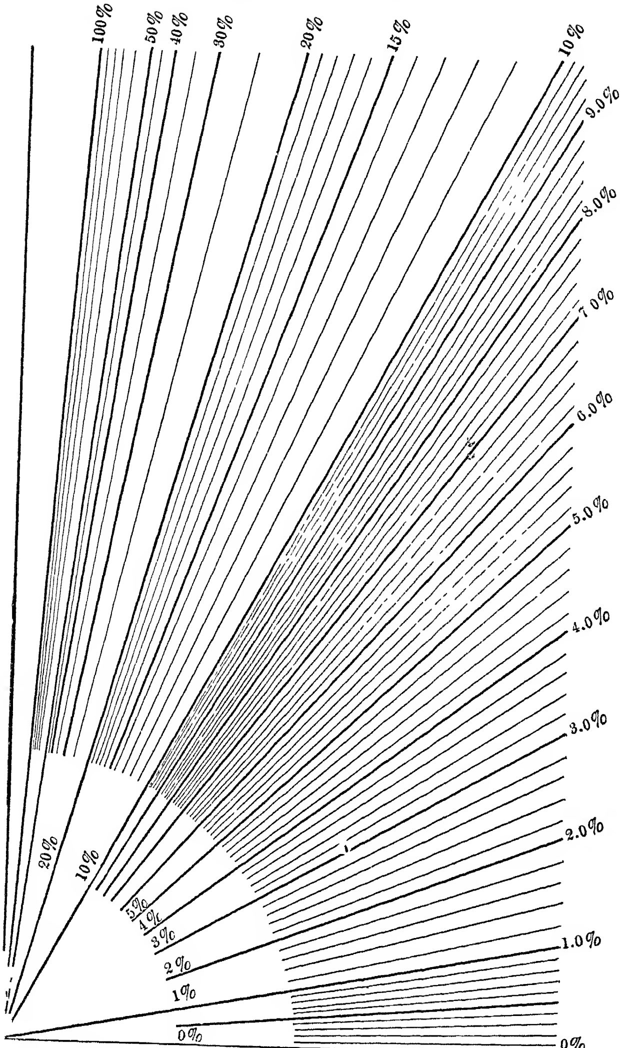


FIG. 49. — Slopes for Yearly Percentage Rates of Increase. (To Accompany Population Diagrams.)

Between 1800 and 1870 Germany grew less rapidly than England, the prevailing rate being a little less than 1 per cent; but after 1870 Germany began to accelerate, the rate between 1900 and 1910 being 1.4 per cent. Austria has grown more slowly, i.e., about 0.7 per cent as an average between 1830 and 1910. The Scandinavian countries have had a normal growth of about 1 per cent, except that in recent years some of the rates have fallen because of emigration as, for example, in Sweden when the rate fell to 0.7 per cent.

France has had a low rate of growth for a century. From 1800 to 1810 it was only 0.5 per cent. This figure steadily decreased until it became practically nothing after 1890. Belgium and Portugal have maintained 1 per cent growths for several decades. Spain has had a slower growth, — about 0.5 per cent. Italy's rate of growth steadily fell between 1825 and 1871 from 0.8 per cent to 0.1 per cent; then it rose to 1.3 per cent and fell off again.

Japan, the only Asiatic country for which there is an accurate record, grew at the rate of 1.1 per cent per year from 1882 to 1910.

In the above comparisons no attempt has been made to secure great accuracy, because some of the changes in populations have been due to altered boundaries, some of the census records are said to be inexact, and they have not been taken on the same dates in different countries. They serve to show that a yearly growth of about one per cent, to use a round number, is not far from a normal for our Western Civilization. They also show that great national crises tend to alter the rates of growth. Rates of growth exceeding 1.5 per cent have been almost always due to immigration.

The data need to be plotted on a larger scale than that used in the diagrams in order to see these changes in rate clearly.

The population of the world has never at any time been determined by count and reliance must be placed on estimates built on very feeble foundations. G. H. Knibbs[1] has assembled many of these estimates and from them has found that between 1804 and 1914 the average annual rate of increase was 0.864 per cent, the rate varying from 1.21 per cent at the beginning of the period to 0.15 per cent at its close. The population of the world in 1914 was estimated by Knibbs to be 1649 million.

Population of the United States. — Turning now to the United States (Fig. 47), we see that from 1790, the date of our first census, to 1860, the rate of growth was very steady at about 3.0 per cent per year. Following the Civil War, the rate fell and remained nearly constant until 1910, i.e., 2.2 per cent to 2.0 per cent. Between 1910 and 1920 it was about 1.4 per cent. An important question here arises. Is this the beginning of a long period of slower growth, or is it but a temporary incident of the war? Predictions of future populations in our American cities must depend on the answer to this question. The author holds the former opinion, — namely, that the rate of growth has taken a new and flatter grade and that, while some of the recent falling off was undoubtedly due to the war, the annual rate of growth for the next fifty years will probably never again exceed 1.5 per cent per year. At this rate the population would reach 200 million by 1962. In all probability the rate will fall steadily until it reaches about 1 per cent per year.

Some have looked forward to a still greater retardation of growth. Professor Raymond Pearl of Johns Hopkins University[2] has worked out a mathematical formula based on

[1] Mathematical Theory of Population, 1917 by G. H. Knibbs, Commonwealth Statistician Australia.

[2] Vitality of the Peoples of America, American Journal of Hygiene, September–November, 1921.

the populations of the United States from 1790 to 1910, and has plotted a line which on ordinary cross-section paper (Fig. 50) is a sigmoid curve. This shows that the point of inflection was passed in 1914 and that a population of 200 million will not be reached until about 2050 and never exceeded. It will be noticed, however, that the change in rate of growth will not be very great during the next forty

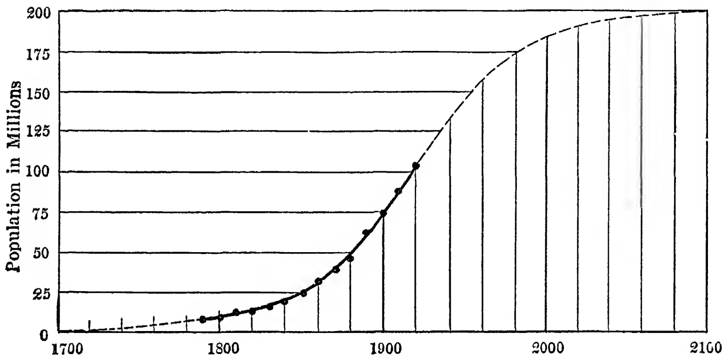


FIG 50.—Estimated Future Population of the United States. (After Pearl)

years, but that after that the population will increase at a lessening rate to a maximum of about two hundred million. Of course, this is merely a mathematical computation and does not take into account changing conditions of living. The point that is of real importance to the present generation is the reversal of the curve. We have been living in a period of acceleration; we are entering upon a period of retardation. The process will be slow but certain.

Fig. 51 shows what the population of the United States would be if the present approximate annual rate of increase of 1.5 per cent were continued; also what it would be if a rate of 1.1 per cent were continued; and what it would be if the increase followed Pearl's formula. A fourth line shows

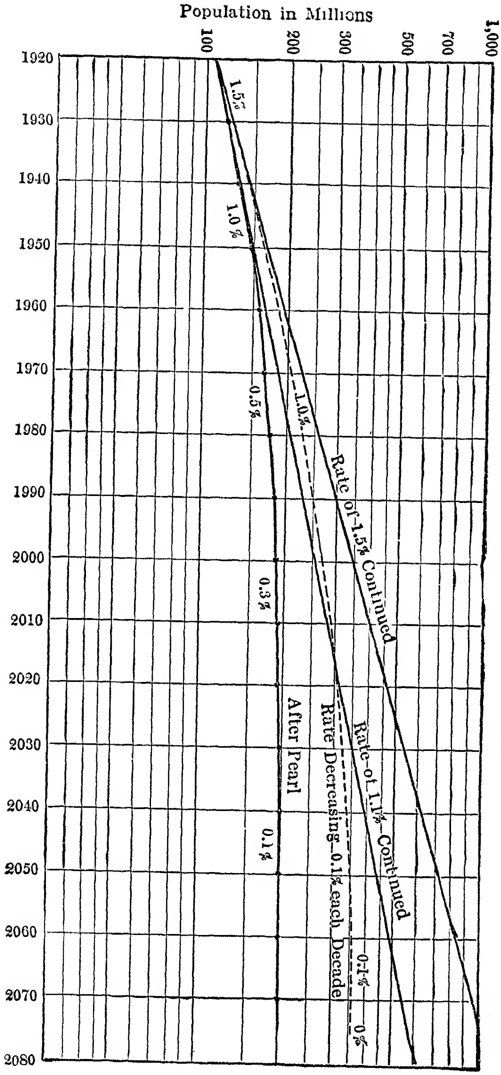


FIG. 51. — United States Population Estimates

what the population would be if the annual rate, starting at 1.5 per cent in 1920, decreased 0.1 per cent per decade.

It must not be forgotten that a growth of 1 per cent per year means a growth of 270 per cent per century and that a rate of 0.5 per cent per year means 165 per cent per century. At the rate of 0.5 per cent per year the population of the United States would be 175 million in the year 2020; 286 million in 2120; 472 million in 2220; 776 million in 2320; 1280 million in 2420; and 2110 million in 2520. In other words, at this rate the population of the United States five centuries hence would be more than the present population of the world. Evidently this cannot be. Some time in the future the rate must drop to much less than 1 per cent per year or catastrophic wars will occur. Our " Western Civilization " must retard its quantitative advance. If it is to bear fruit worthy of its efforts it must look to quality and not to quantity. Nations should be judged not by their size but by the happiness, comfort and well being of their people. This is as true of cities as it is of nations.

Population of the several states. — Figs. 52 to 61 show the populations of the several states by sections.

New England as a section has grown at a fairly constant rate since 1790, i.e., 1.6 per cent per year. (Fig. 52.) The break in 1860–70 was only temporary. The six New England states fall into two well marked groups. Massachusetts, Connecticut, and Rhode Island, which are essentially industrial, accelerated greatly about 1840 and have maintained rates of about 2 per cent per year. About the same time the rates of Maine, New Hampshire, and Vermont gradually fell off, until in recent years they have been less than 0.3 per cent and, in Vermont, nothing. This has been due, of course, to emigration and the drift to the industrial centers.

In the Middle Atlantic States, (Fig. 53), New York and

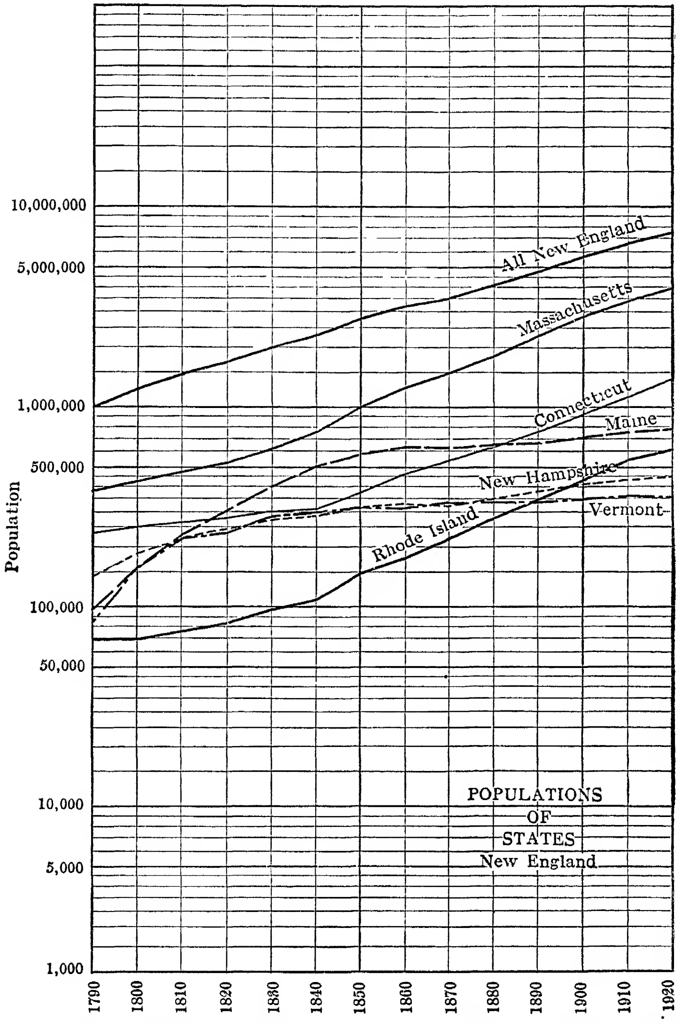


FIG. 52. — Population of the New England States, 1790 to 1920, plotted on Semi-logarithmic paper.

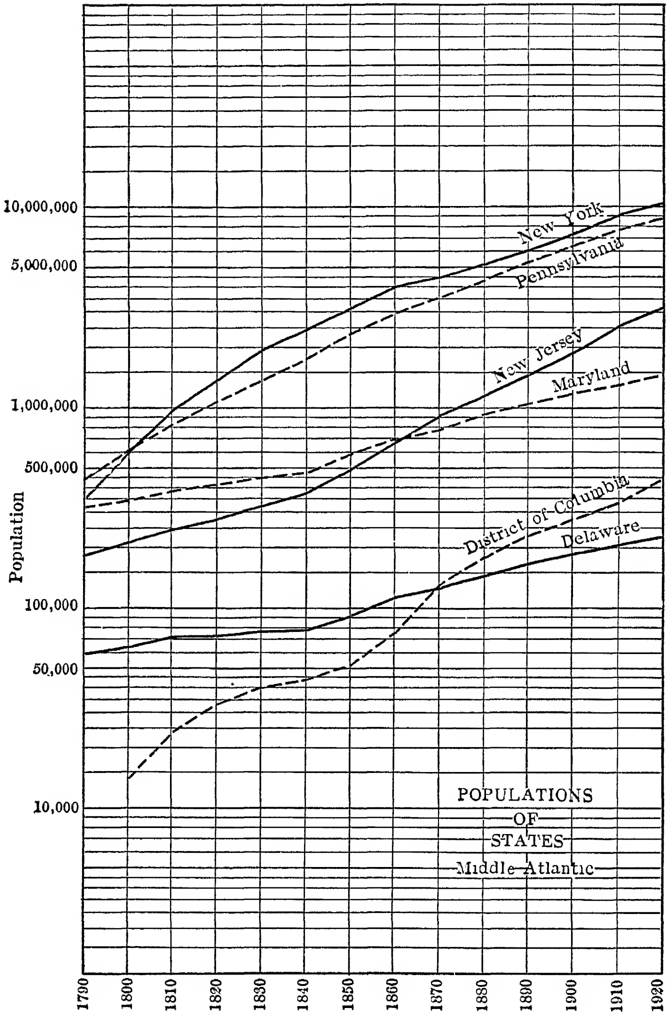


FIG. 53. — Population of the Middle Atlantic States, 1790 to 1920, plotted on Semi-logarithmic paper.

Pennsylvania had an early rapid growth, rates of 5 per cent, 4 per cent, and 3 per cent being observed. Since the Civil War the rates have been between 1.5 per cent and 2 per cent. New Jersey's most rapid rate of growth was between 1840 and 1870 when the rate was 3 per cent, but since then the rate has fallen to about 2.5 per cent. Delaware and Maryland have grown more slowly.

The South Atlantic States (Fig. 54) had variable rates of 1 per cent to 4 per cent before the Civil War; but since then have grown steadily. Florida has maintained a 3 per cent growth since 1860. The drop in Virginia after 1860 was due to the settling off of West Virginia.

The East North Central States (Fig. 55),— Ohio, Indiana, Illinois, Michigan, and Wisconsin, — grew at a very rapid rate between 1800 and 1850, rates of 15 and 20 per cent a year being observed. Since the Civil War the rates have been lower. Indiana has dropped to 1 per cent, but Michigan's population increased at a 2.6 per cent rate between 1910 and 1920.

The East South Central States (Fig. 56) have had the same general history, but the Gulf States, Alabama and Mississippi, have in recent years grown faster than Kentucky and Tennessee, the rates of the first two being about 2 per cent and the latter 1 per cent or less.

The West North Central States (Fig. 57) had rapid growths at first, but since 1890 the rates of Missouri, Iowa, Kansas and Nebraska, prairie states, have flattened greatly, being not far from 0.5 per cent. Minnesota has not dropped as much. The Dakotas grew rapidly between 1890 and 1910, when the rates fell off.

The West South Central States (Fig. 58) have varied a good deal. Louisiana since the Civil War has had a 1.8 per cent growth; Texas, a 10 per cent growth followed by rates about 3 per cent; Arkansas, an early spurt of 25 per cent,

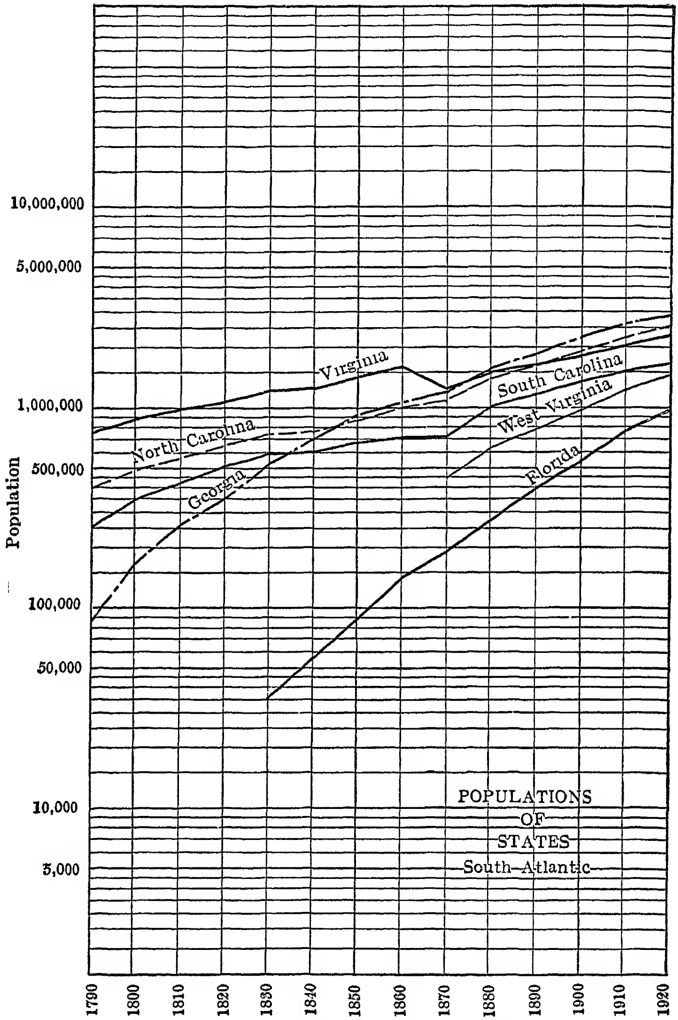


FIG. 54. — Populations of the South Atlantic States, 1790 to 1920, plotted on Semi-logarithmic paper.

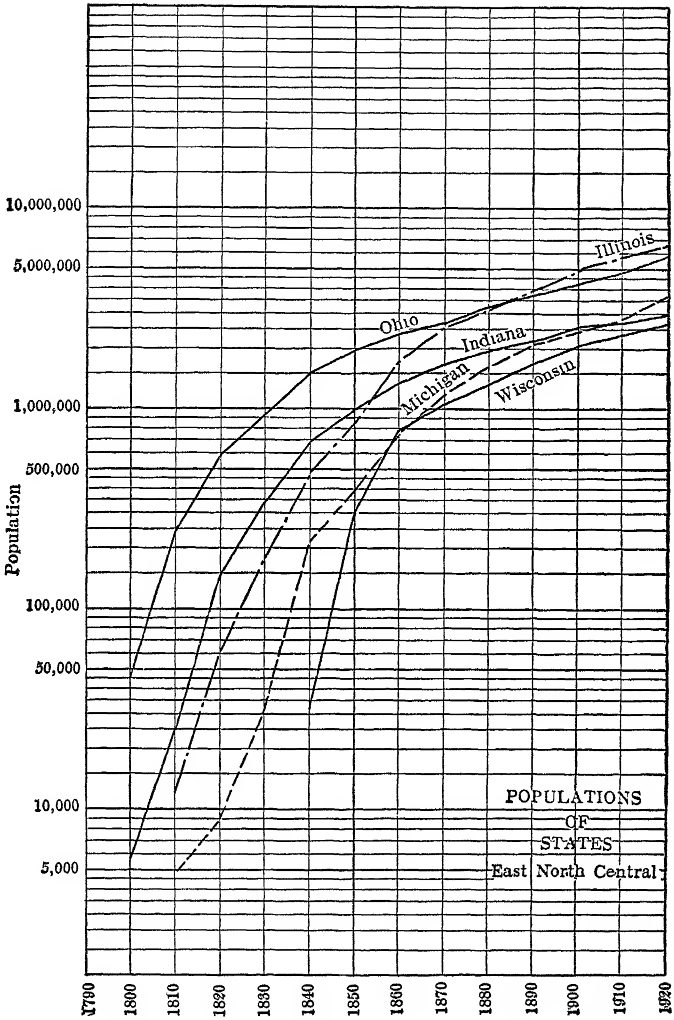


FIG. 55. — Populations of the East North Central States, 1800 to 1920, plotted on Semi-logarithmic paper.

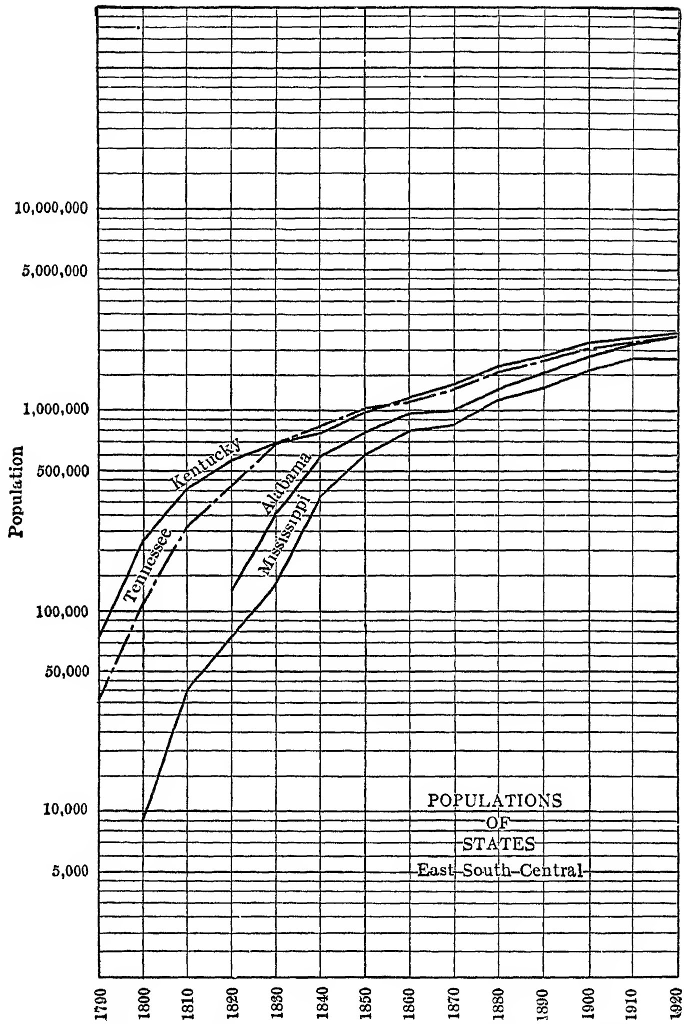


FIG. 56. — Populations of the East South Central States, 1790 to 1920, plotted on Semi-logarithmic paper.

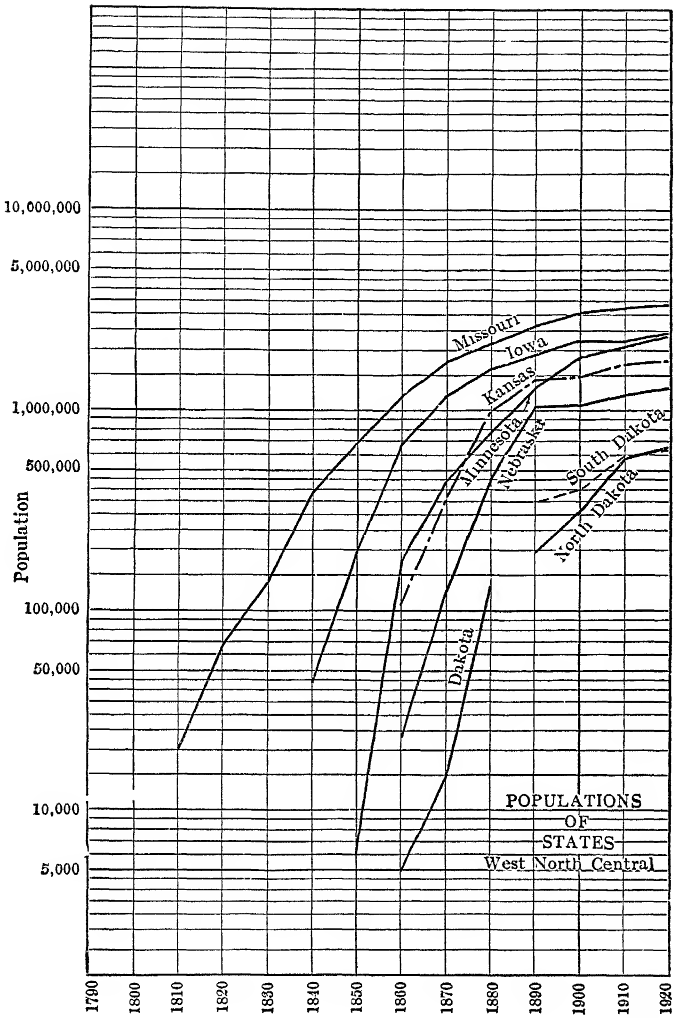


FIG. 57. — Populations of the West North Central States, 1810 to 1920, plotted on Semi-logarithmic paper.

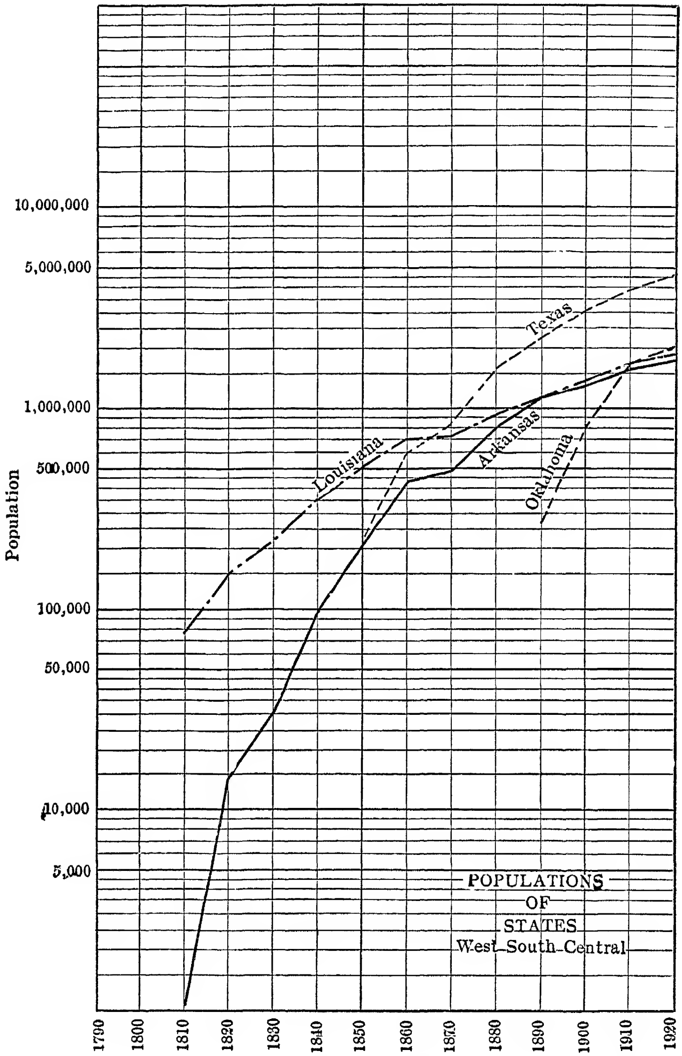


FIG. 58.— Populations of the West South Central States, 1810 to 1920, plotted on Semi-logarithmic paper.

falling little by little to 1.5 per cent; and Oklahoma, a similar rapid growth with a recent set-back.

The North Mountain States, — Montana, Idaho, and Wyoming, — are still small but the rates of growth are high, — i.e., 3 per cent to 5 per cent. (Fig. 59.)

The South Mountain States, — Colorado, Utah, Arizona, and New Mexico, — have grown rapidly but, except for Arizona, the rates fell off during the last decade. Nevada, a mining state, has shown both gains and losses. (Fig. 60.)

The Pacific States, (Fig. 61) — Washington, Oregon, and California, — have maintained high rates of growth varying from 15 to 20 per cent in the gold fever days to 4 per cent and 8 per cent before the Great War. In the last decade Washington and Oregon had growths of 1.6 per cent and California, 3.8 per cent.

Looking at the states west of the Alleghanies in a general way, it will be seen that they all had their period of early settlement, lasting from 30 to 60 years during which the rates of growth were between 5 per cent and 25 per cent per year, followed by a period of more conservative development, which has depended largely upon the natural resources but which has been influenced also by industrial development. No rates of growth comparable to those which existed fifty years ago may ever be expected again, unless extraordinary conditions arise.

Biological factors. — With this general background of population statistics for different states and nations let us now consider briefly some of the biological factors which enter into the problem and which are described at greater length in the next chapter.

If we take a country like Sweden, for which there exists a long and accurate record of vital statistics, we find that although the birth-rates and death-rates have both been trending downwards for a long time the excess of birth-rates

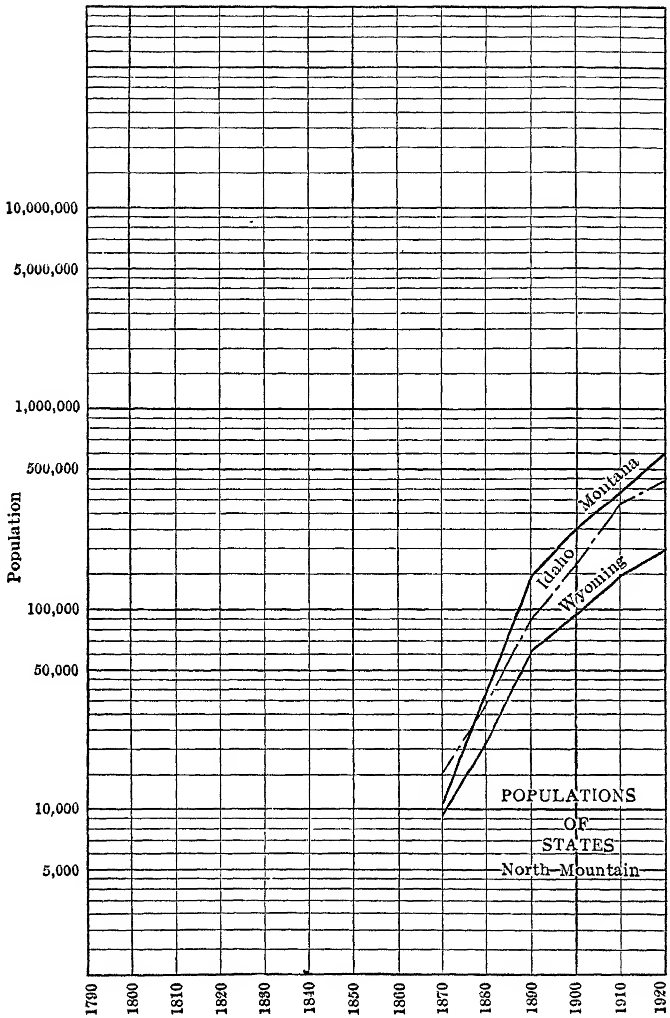


Fig. 59. — Populations of the North Mountain States, 1870 to 1920, plotted on Semi-logarithmic paper.

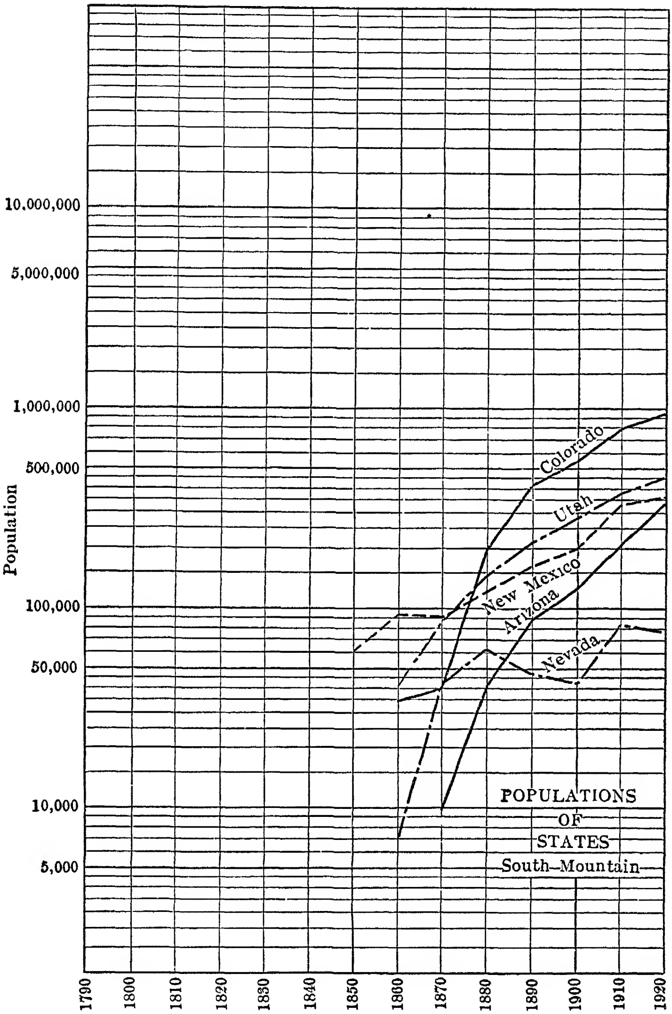


FIG. 60. — Populations of the South Mountain States, 1850 to 1920, plotted on Semi-logarithmic paper.

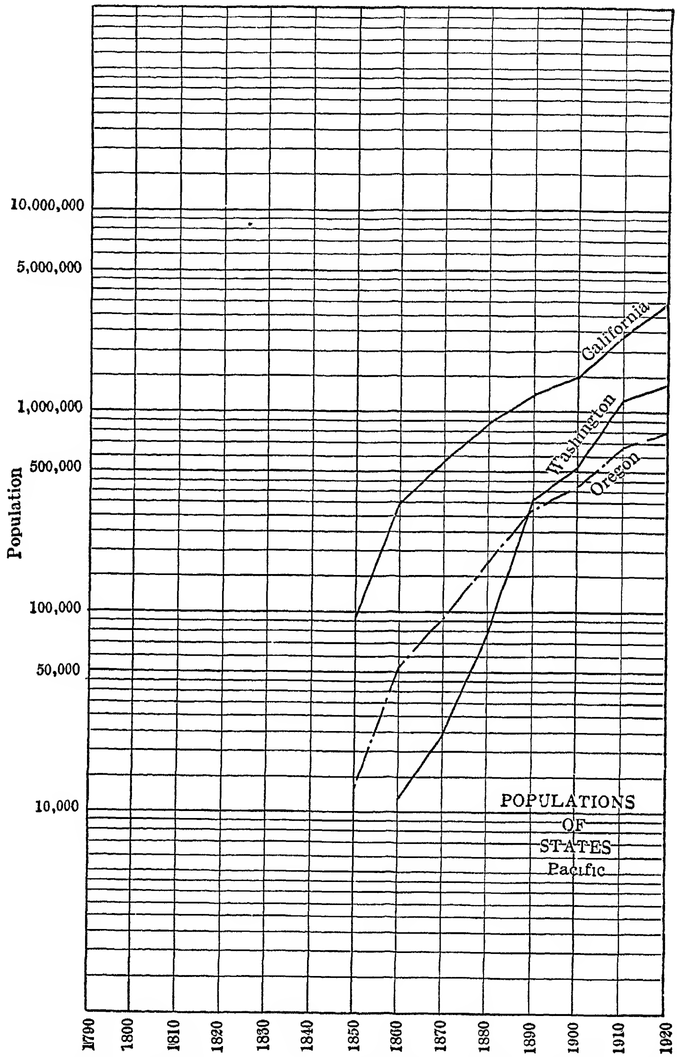


FIG. 61. — Populations of the Pacific States, 1850 to 1920, plotted on Semi-logarithmic paper.

over death-rates has been, on the whole, rising, although there have been marked fluctuations from year to year (Fig. **63**). Marriage-rates and birth-rates are influenced by social and economic conditions and by wars. The violent changes in death-rates are due to epidemics of disease, famines, and wars. One thing is conspicuous from the Swedish data, — namely, the smaller fluctuations in the vital rates of recent years. These indicate more stable economic conditions and better health. And yet, as if to contradict this statement, we have recently seen the effect of two cataclysms, the Great War of 1914–18 and the Great Influenza Epidemic of 1918 both of which increased the death-rate. Fig. **63** also shows that for nearly a century the excess of birth-rates over death-rates has fluctuated around 10 per 1000, or 1 per cent per year, thus corresponding approximately with the average population increase, 1.1 per cent, already referred to. There are no similar records available for the United States as a whole, but for a few states, Massachusetts for example, it is possible to ascertain the excess of birth-rates over death-rates for a fairly long period. Between 1850 and 1860 the natural increase rose from 0.95 to 1.2 per cent. During the Civil War it fell to 0.14 per cent; then rose to nearly 1 per cent and back again to 0.5 per cent in 1880, — these changes being influenced more by the birth-rates than the death-rates. Since 1890 the death-rate has fallen steadily and the excess of births over deaths has steadily risen until in 1914 it was 1.1 per cent. All these figures are so much lower than the actual population growths for the state that the effect of immigration is plainly to be seen. In recent years immigration has been falling off, as the following approximate figures show: —

Decade.	Total increase. (Per year.)	Natural increase. (Per year.)	Immigration. (By difference)
(1)	(2)	(3)	(4)
1880–1890	2.4%	0.6%	1.8%
1890–1900	2.4	0.8	1.6
1900–1910	1.8	0.9	0.9
1910–1920	1.4	1.1	0.3

It may be observed from the Massachusetts data, as well as from data for other states, that when the natural increase has fallen below 0.5 per cent per year it has soon afterwards risen quickly to more than 0.5 per cent and in fact has usually tended to rise to 1 per cent.

It must not be inferred that the relations between birth-rates and death-rates are simple; as a matter of fact, they are of extraordinary complexity. One important factor is often overlooked, — namely, the changing age composition of the people. Another is the age of marriage. Late marriages tend to reduce the birth-rate. Dr. Raymond Pearl emphasizes the ratio of births to deaths, a subject discussed on page 268.

Economic factors. — The well known law of Malthus is that if, as time goes on, food production increases in an arithmetical ratio while population increases in a geometrical ratio population must inevitably overtake and surpass the food supply. That large populations tend to increase geometrically has already been shown; but the arithmetical increase in food supply is less certain. It depends upon natural resources, especially agricultural resources, and man's knowledge and ability to utilize them. It may also be said to depend upon man's possible adaptability to new food supplies. The Malthusian doctrine has been the storm centre of all sorts of discussions, — social, economic, and religious. It does not help us much in estimating the future population of cities, yet it does stand as a sort of foundation theory, showing the close relation between population growth and economic conditions.

In the first place, economic conditions affect the marriage-rate and the birth-rate. What is of more immediate importance to our subject, economic and industrial conditions control migration. The annual 3 per cent growth of the United States before the Civil War was due to an immigration inspired largely by hope of economic reward. The drift of people from the rural districts to the cities which began in force about 1840 was also due to economic reasons. And now we see people following industry from city to city. We have not seen as yet any disposition to return to the farm, although the general good of the country demands it. These migrations are, of course, influenced by mixed motives, — political, social and religious ideas having sometimes an important influence. These migrations are often sudden; cities sometimes grow with great rapidity, — Detroit, for example. In providing public utilities, such as sources of water supply and sewerage facilities, some factor of safety should be allowed for sudden jumps in population due to industrial invasion or some unforseen growth.

Effect of immigration. — Everyone knows that immigration has been an important factor in the population increase in the United States. Mention has already been made in Chapter V of the fluctuations in immigration. It is important to learn how this influx of people from other countries has affected the percentage rates of increase. This has been computed approximately by decades and the results are shown in Fig. 47. The short dotted lines show the rate of increase of population after deducting from the population increments given by the censuses the immigration during the decade. These rates are materially lower than those shown by the full line. During the ten years between 1910 and 1920 the rate was only 0.7 per cent per year. This low figure was, of course, due to the war. Unfortunately we have no published data as to the emigration during that decade. Probably the next ten years will show a natural increase in population not far from the 1.1 per cent mark.

Law of diminishing rate. — It may be laid down as a general principle that as cities become larger their percentage rate of growth decreases. This may be true even when the annual increments are becoming larger.

For example, let us suppose that a city of 100,000 receives by immigration 3000 new people each year, and that the natural rate of increase is 1 per cent per year. The population increase would be as follows: —

		Population	Annual percentage increase.
At beginning of first year		100,000	
During first year, immigration,	3,000		
natural increase	1,000		
At beginning of second year		104,000	4.00
During second year, immigration	3,000		
natural increase	1,040		
At beginning of third year		108,040	3.88
During third year, immigration	3,000		
natural increase	1,080		
At beginning of fourth year		112,120	3.77

A study of the populations of American cities from 1790 to 1920 shows that this law generally holds but that there are many cases of erratic variations from it due to the development of industries which suddenly attract large numbers of workers. The ratio of urban to rural population in the United States has been steadily rising for a long time. In 1840 it was 1 to 10.8; now it is 1 to 1.3. With the rural districts already drained and with immigration restricted it is to be expected that the percentage growth of American cities will fall off materially. Furthermore, there are forces within the cities themselves which are tending to retard growth. The evils of congested housing, high buildings, streets crowded with automobiles, and things too numerous to mention, taken in connection with the increasing demand for better standards of living are giving impetus to the decentralization movement.

Saturation. — An important internal factor in city growth is what may be called saturation of territory. When an area has grown to a certain density it ceases to grow; the population locates around the area, not in it. Density of population depends largely upon the heights of buildings. An area fully built up on a two-story basis may have its density doubled by tearing down the two-story houses and erecting four-story houses. But there are limits to this process because streets as well as buildings become congested and regulation of buildings becomes necessary in order that all people may have somewhere near to equal rights in such natural agents as light and air. No definite limit can be set for saturation of territory, but by studying the populations of wards and sections of cities this can be found approximately for any given community. Factories and business drive out residents, and small areas may become industrially or commercially saturated.

Effect of emigration. — It must not be forgotten that cities may be influenced by local emigration as well as by immigration. Only occasional examples of this have been seen thus far in the United States. But we are a new nation and our cities have not yet experienced the saddening sights of decay. These are not at all uncommon in Europe and our time will come. Basing judgment on Pearl's curve, our children and even our grandchildren are not likely to witness the decline, but their grandchildren may live to see the population curves topple.

Expansion of area. — In predicting future populations it must be observed that cities often grow in area as well as in population. Annexations are so erratic, however, that nothing approaching a law can be established. **Fig. 45** shows the population of the old city of Boston also the population of the city including its annexations. Apparently the old part of the city became almost "saturated" many years ago. The present city still has much unsaturated territory, but looking ahead it seems likely that the great future growth will occur in the suburbs, — that is, in the outer zones of the metropolitan area.

In making population predictions for any city, account should be taken of past annexations and of future annexations likely to occur within the period of the estimates.

Method of forecasting. — In making estimates of the future population of a city, it is necessary to consider both the tangible and the intangible evidences. The best mode of procedure is as follows: —

1. Collect all the available population data, including census records, areas, densities of populations in subdivisions of area, annexations, etc.

2. Plot the past census populations of the city on semi-log paper. Plot also the decadal increments on semi-log paper.

3. Extend the population curve forward according to the general trend of the plotted points. Regard this merely as a tentative estimate.

4. Plot on the same sheet a line having a slope of 1.1 per cent per year as a guide line showing the average annual growth of population as already described.

5. Plot also lines showing the population growth in larger contiguous areas in order to be guided by them also.

6. Plot also population growths of older and larger cities.

7. Make a list of the intangible factors involved such as

the birth-death ratio, local movements of population, as shown by various data such as change of industries, building permits, new water and gas connections, etc.

8. On the basis of these various guides modify the tentative estimate, increasing or decreasing the annual percentage rates of growth on the basis of all the evidence, remembering that the natural tendency is for the annual rate of increase to approach 1 per cent as a round number.

The prediction of future population depends in the last analysis upon judgment and not upon mathematical computation. The latter is merely a guiding framework. In planning structures for future use engineers naturally like to make their estimates sufficiently liberal to yield a certain factor of safety, and probably this is justified. In estimating the future water supply requirements it is better to be too high than too low. But on the other hand, if bonds are issued, the payment of which depends upon the future population, an oversanguine estimate may result in extravagant expenditures which will ultimately cause financial hardship. It is important, therefore, that the best possible estimate be made.

High and low estimates. — As a rule American engineers have made their predictions of future populations too high. They have not given sufficient consideration to the law of decreasing rate, and, as a class, they have not studied sufficiently the trend of population growth in states and nations or the biological and economic factors involved. On the other hand, there have been some notable cases of underestimation. A few examples of unfulfilled estimates may be mentioned.

In 1865 James P. Kirkwood, a well known civil engineer, estimated that the population of Cincinnati would be 431,644 in 1890; actually it proved to be 297,000. At Rochester an estimate made in 1889 claimed that the population in 1910 would be 283,459; actually the city grew to only 218,149. In 1895 Frederick P. Stearns estimated that the population of Cambridge in 1920 would be 146,720, but the census of 1920 showed only 109,694. At Winnipeg in 1897 a certain estimate of the probable population in 1907 was made, but when 1907 arrived the population was double the estimated figure. These cases are exceptional. As a general rule engineers' estimates of future population have been close enough for practical purposes. For reasons mentioned, it is going to be increasingly difficult to make reliable estimates, and engineers and others will have to give more attention to demographic studies than they have given in the past.

CHAPTER VII

GENERAL DEATH-RATES, BIRTH-RATES AND MARRIAGE-RATES

Gross death-rates (general death-rates.) — Stated simply, the death-rate is the rate at which a population dies. It is the ratio between the number of persons who die in a given interval of time and the median number of persons alive during the interval. Unless otherwise specified the interval of time is considered to be one year. For the sake of comparison the ratio mentioned is reduced to the basis of some round number of population, generally 1000. Not until such reduction is made may we consider this ratio as a " rate."

The computation is, of course, very simple. If in the year 1917 the number of deaths in a given city was 5710 and the population on July 1 of that year was 390,000, then the death-rate was:

$$5710 \div 390,000, \text{ or } 14.6 \text{ for each thousand.}$$

The death-rate for 1917 was therefore 14.6. We sometimes call this the " general " death-rate because it refers to the general population. Sometimes it is called the " crude " death-rate to distinguish it from rates corrected and adjusted in various ways. Or it may be called the " annual " death-rate. This is unnecessary, however, as death-rates are always assumed to refer to a year as the basis unless stated to the contrary. Perhaps the best term of all would be the " Gross death-rate," but this term is not as common.

Death-rates may be based on 10,000 or 100,000 or 1,000,000 of population, but 1000 is the common base for all general rates. The higher numbers, however, are often used for special rates, as described in the next chapter.

The method of estimating mid-year population was fully described in the preceding chapter.

Precision of death-rates. — The accuracy of a death-rate depends upon the accuracy of the number of deaths and the correctness of the estimated population. One or both of these may be in error. Only in a census year can the death-rate be computed from actual facts, because only in a census year is the population known by actual count. In other years, the population is *estimated*, and hence the death-rate based upon it must also be regarded as an *estimate*. Incorrect estimates of population obviously must produce incorrect death-rates. If this fact be kept in mind it will prevent one from drawing unwarranted conclusions in comparing rates which differ from each other by small amounts.

It is quite common to see the gross death-rate, referred to 1000 persons as a basis, expressed to the second place of decimals. This is warranted in the case of large populations for then the figures in the second decimal place have a significant value. It is not warranted for small populations. This, it will be remembered, was discussed in Chapter II, but the following figures will further illustrate the point.

In *A*, with a population of 1000, the number of deaths was 16 and, of course, the death-rate was 16. An error of one death, the smallest possible error, would have made the deaths 17 (or 15). In *B*, with a population of 10,000, an error of one death would have changed the rate from 16.0 to 16.1; in *C*, population 100,000, from 16.00 to 16.01, and in *D*, population 1,000,000, from 16.000 to 16.001. In a

TABLE 43

PRECISION OF DEATH-RATES

City.	Population.	Number of deaths.	Death-rate
(1)	(2)	(3)	(4)
A	1,000	16	16 00
	1,000	17	17 00
B	10,000	160	16 00
	10,000	161	16.10
C	100,000	1,600	16 00
	100,000	1,601	16 01
D	1,000,000	16,000	16 00
	1,000,000	16,001	16 001

city of less than 10,000 population it would obviously be unreasonable to use two decimal places.

Similarly the following figures show the differences in population required to change the death-rate from 16.00 to 16.10 in cities of different size, the actual numbers of deaths remaining the same.

TABLE 44

PRECISION OF DEATH-RATES

City.	Death-rate.	Number of deaths.	Population	Difference in population.
(1)	(2)	(3)	(4)	(5)
A	16 00	16	1,000	6
	16 10	16	994	
B	16 00	160	10,000	62
	16 10	160	9,938	
C	16 00	1,600	100,000	621
	16 10	1,600	99,378	
D	16 00	16,000	1,000,000	6211
	16 10	16,000	993,789	

It will be noticed that in all cases the percentage difference in population is the same, *i.e.*, 0.62 per cent. This percentage varies according to the death-rate. To alter the death-rate from 12.00 to 12.10, for example, if the number of deaths remained the same, would require a change of population of 0.83 per cent. The following figures show the percentage change in population required to alter the death-rate by 0.10 per 1000 from certain given death-rates.

TABLE 45

Change of rate from	Percentage change of population.
(1)	(2)
20 00 to 20 10	0 50
19 00 to 19 10	0 52
18 00 to 18 10	0 55
17 00 to 17 10	0 58
16 00 to 16 10	0 62
15 00 to 15 10	0 66
14 00 to 14 10	0 71
13 00 to 13 10	0 76
12 00 to 12 10	0 83
11 00 to 11 10	0 90
10 00 to 10 10	0 99

As a rough and ready rule we may therefore decide that for places smaller than 1000 the death-rate shall be stated in whole numbers; for places between 1000 and 100,000 one decimal shall be used; for places above 100,000 two decimal places shall be used.

Corrected death-rates. — What shall be taken as the number of deaths in a community? Shall non-residents who die within the geographical limits be included? Shall residents who die away from home be referred back to the place where they live? In other words shall the place for which the death-rate is computed be considered as a geographical area or as a community of persons? The answer must depend upon the use which is to be made of the facts.

The Bureau of the Census, looking at the matter in a broad way, takes the geographical point of view. It can hardly do otherwise. By recording deaths in the place where the deaths actually occur there is far less danger that all deaths will not be recorded and that no death will be counted twice than if a process of distribution by actual residence were attempted. It may be laid down as a general rule that in computing gross death-rates all deaths within the defined area shall be included and no others; that is, gross death-rates shall have a geographical basis.

This does not prevent the making of corrections to allow for local conditions. Often such corrections are desirable. If a hospital is located in a suburban town near a large city the deaths in that hospital should be included in the general death-rate of the town; but this figure could not be taken as an index of the hygienic or sanitary condition of the town. For such a purpose another rate — a corrected rate — should be computed, leaving out the hospital deaths. This might be called the *local death-rate.* This rate should not be used in place of the gross death-rate, but in addition to it.

If, besides the omission of non-resident deaths in institutions, the attempt is made to find and include the deaths of residents who have died away from home we might call the result the "*resident death-rate.*"

The gross death-rate, or general rate, is best for purposes of national or state record. The local rate is best for environmental studies. The resident rate is useful for social and political studies.

In New York city the health department publishes a general death-rate and also a "corrected" death-rate in which the deaths are redistributed among the five boroughs on the basis of residence. This is because so many persons residing in one borough are taken to hospitals in other boroughs. In some cases this makes an important difference. For the week ending Mar. 23, 1918, the death-rates for the five boroughs were as follows:

TABLE 46

DEATH-RATES IN NEW YORK CITY

Borough.	General death-rate	Resident death-rate
(1)	(2)	(3)
Manhattan	20 32	20 30
Bronx	20 20	17 68
Brooklyn	18 98	20 04
Queens	20 71	20.98
Richmond	25 13	18 98

On the basis of the gross death-rate Richmond is seen to have a death-rate much higher than Manhattan, but its resident, or "corrected," rate is lower than that of Manhattan.

At the end of a year a *preliminary* death-rate is often computed and published. Afterwards delayed reports of deaths are received and this necessitates a correction. The term "corrected" death-rate is sometimes applied to the new result. This of course is a proper use of the adjective, but a better term would be "*final*."

The term "corrected death-rate" has been used by some writers as synonymous with the "standardized death-rate," described on page 292. This use of the term is unfortunate and should be avoided.

Properly the word "corrected" should be applied only to death-rates in which changes are made in the number of deaths.

Revised death-rates. — Inasmuch as death-rates are based on *estimated* populations in post-censal years, and as these estimates are usually less accurate than intercensal estimates, it is always wise after each new census to recompute the death-rates for the preceding intercensal years if it is found that the new census is different from the estimated population. Sometimes the resulting changes are slight, but they may be considerable. The rates based on these revised estimates of population should be called "*revised death-rates.*"

Variations in death-rates in places of different size. — Wide fluctuations in the general death-rates from year to year are to be expected in small places. Having a small population a change of one death in a year may considerably alter the rate. In larger populations the fluctuations are less marked. This is well illustrated by the death-rates of three places in Massachusetts, — Boston (population 686,092 in 1910), Springfield (88,926) and Yarmouth (1420). Fig. **62** shows that the death-rate for Boston changed slowly, that of Springfield, although lower, fluctuated more, while that of Yarmouth varied through wide limits.

This very well illustrates what is sometimes called the principle of large numbers.

Errors in published death-rates. — It is necessary to use published death-rates and birth-rates with great caution. The old reports especially contain many unsuspected errors. For example, it was not at all uncommon ten or twenty years ago for the population of one census to be used year after year as the basis of death-rates, or until a new census was taken; that is, no intercensal estimates were made. Even the old registration reports of Massachusetts are full of inconsistencies and cases of disagreements. In the following table the general death-rates are given in the second column as

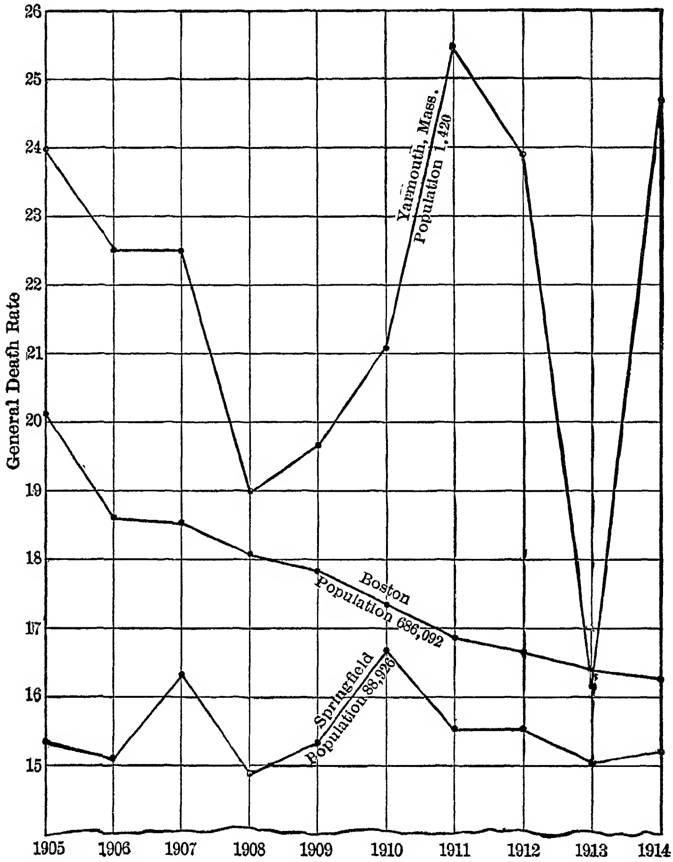


FIG. 62. — Comparison of Death-rates in a Large City, a City of Moderate Size and a Small Town.

they appeared originally in successive annual reports. In the third column the rates for the same years are given as published in the annual report for 1915, the rates having been recomputed.

TABLE 47

DEATH-RATES IN MASSACHUSETTS

Year	As given originally in successive annual reports	As given in report of 1915 (recomputed)
(1)	(2)	(3)
1905	16 8	16 7
1906	16 9	16 4
1907	18 1	17 2
1908	17 2	16 0
1909	17 0	15 5
1910	16 2	16 1
1911	15 8	15 8
1912	15 6	14 9
1913	15 9	14 9
1914	14 5	14 5

Rates for short periods. — The general death-rate is always computed on the basis of a year.

Strictly speaking the monthly death-rate would be the number of deaths occurring in the month divided by the estimated population for the middle of the month; and the weekly death-rate would be the number of deaths in a week divided by the estimated Wednesday population for that week. This practice would reduce population estimates to an absurd degree of precision. The months moreover do not all have the same number of days. On account of the varying estimates of population the sum of the monthly rates would not equal the annual rates.

It is much better for many reasons to reduce all rates for short periods to the basis of a year, and to use the population estimated for July 1 for all months and weeks of the same year. Account must be taken, too, of the varying length of the months, and of the fact that a year is not exactly fifty-two weeks.

To find the death-rate for January we therefore multiply the number of deaths in January by $\frac{365}{31}$, and divide by the estimated population for July 1. For the months of thirty days the multiplier is $\frac{365}{30}$; for February it is $\frac{365}{28}$ in ordinary years, and $\frac{366}{29}$ in leap years.

To find the death-rate for any week in the year we multiply the number of deaths in the week by $\frac{365}{7}$ and divide by the population estimated for July 1st.

Birth-rates. — Birth-rates are computed in the same way as death-rates. We may have general rates, local rates, and resident rates; preliminary rates and final rates; corrected rates and revised rates. Weekly and monthly rates are reduced to a yearly basis.

One thing should be always remembered. If a child is born dead, that is if it is a "still-birth," it is not considered by statisticians as a birth although the Model Law requires that a still-birth be reported both as a birth and as a death in order to have the desired facts placed on file. When making up statistical tables, tables of births should include only living births. Still-births should be placed in a class by themselves. In some places, still-births have been included with the living births, and in comparing old birth-rates with present rates this must be kept in mind. It must be remembered also that birth registration is usually less complete than the registration of deaths.

Relations between birth-rates and death-rates. — The relations which exist between general birth-rates and general death-rates are very complicated. It is easy to say that because of a naturally high infant mortality, which until recently has seldom been less than 10 per cent and which in some countries is more than 25 per cent, the birth of many children means many deaths and hence a high birth-rate means a high death-rate. To a certain extent this is true. It is true for a sudden increase in the birth-rate and its effect may last for five or ten years perhaps if the high birth-rate keeps up. But a high birth-rate adds to the population, and this increases the denominator of the birth-rate. Also most of the babies will within a few years become children and enter age groups where the specific death-rates are low. If a high birth-rate is long continued it may actually reduce the general death-rate. Fifty or sixty years after a high birth-rate there would normally be an excess of persons living within the advanced age groups for which the specific death-rates are high and rapidly increasing.

Instead of becoming confused by trying to think out these puzzling relations, and especially so because wars and migrations upset all such reasonings, it is better to regard the birth-rate as something which together with deaths and migrations controls the age composition of the people. Conversely the age composition of the people influences both the given birth-rate and the general death-rate. One cannot think clearly on this subject without cutting loose from general rates and studying specific rates by ages both for births and deaths.

Fecundity. — From a social standpoint birth-rates computed in the usual way give an inadequate idea of some of the most important matters concerning the increase of population, for they are merely ratios between births and total populations, and the ratio of child producers to the population is not constant. If we are to follow the statistical principle of comparing things which are logically comparable we shall compute other ratios, such as that between births and women of child bearing age and that between births and married women of child bearing age, and we shall separate legitimate from illegitimate births, and take into account still-births, though always keeping them separate from living, or true statistical births.

What are the chief factors which control natality, that is, the reproduction of population? The number of marriages; the effective duration of these marriages, that is the number of years between the age of the bride at marriage and the natural age when child-bearing ceases; and the frequency with which conception occurs. The number of marriages depends upon the age and sex composition of the population and upon economic and social conditions. The effective duration of marriage depends upon the age at marriage, especially the age of the bride. Obviously if marriage occurs late in life the effective duration of marriage is shortened. The frequency of conception is said to depend to a slight extent upon the infant mortality as a shortening of the period of suckling reduces the child-bearing interval; but to a considerable extent this is a matter which is, or may be, controlled by the husband and wife. The number of still-births also has an influence on the intervals between living children. Natality is influenced by other minor factors such as the frequency of multiple births.

Körösi[1] and others have attempted to compute tables of natality, similar to the life tables described in Chapter XV. Statistics for Budapest indicated that the age of maximum fecundity for females reached its maximum between the eighteenth and nineteenth years, falling steadily to age fifty when it practically ceased. Males attain their maximum fecundity at the age of about twenty-five, after which there is a steady decline to age sixty-five or thereabouts. It is understood that these figures are not physiological limits necessarily, but include social and economical considerations. Late marriages therefore reduce the number

[1] 1899, Newsholme, Vital Statistics, p. 667.

of resulting children. Combinations of brides and grooms of different ages results in different probabilities of births. The following figures given by Korosi illustrate this. The percentages refer to the probability of a birth occurring in a year.

TABLE 48

RELATION OF AGE TO FECUNDITY

Probability of a birth occurring within a year

Fecundity of mothers.				Fecundity of fathers				
Age of father.	Age of mother. 25 yrs	30 yrs	35 yrs	Age of mother.	Age of father 25 yrs	35 yrs.	45 yrs	55 yrs.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Per cent	Per cent	Per cent		Per cent	Per cent	Per cent	Per cent
25–29	36	25	21	20	49			..
30–34	31	24	20	20–24	43	31	16	.. .
35–39	27	22	19	25–29	31	27	18	. .
40–44		17	14	30–34	33	24	14	8
45–49		14	11	35–39		19	12	7
50–54	. . .		11	40–44		7	6	3

Nationalities differ considerably in the number of children per marriage. For example, in Russia, the number of children per marriage in 1894 averaged as high as 5.7, while in France it was only 3.0. During recent years in most countries the birth-rates have fallen considerably. In studying this subject in its social relations, these natural conditions of fecundity as influenced by the age composition of the people, the age of marriage and the influence of nationality must be taken into account.

Illegitimate births. — Children born to unmarried women are called illegitimate or ex-nuptual. In computing general birth-rates they are included, but in the study of social problems they should be considered by themselves. The illegitimate birth-rate is the ratio between illegitimate births and the total population expressed in thousands. The percentage of illegitimacy is sometimes computed, that is the ratio between illegitimate and total births, but this ratio may be misleading as the total number of births depends on the marriage-rate, which fluctuates more or less according to economic conditions. As a measure of morality a more useful ratio is that between ex-nuptual births and unmarried women of child-bearing age. It is just as important to consider the age and sex composition of a population in studying illegitimate births as in studying all births.

Newsholme has given the following interesting comparisons between two sections of London, Kensington, an aristocratic fashionable district, and Whitechapel, a poor industrial parish.

TABLE 49

BIRTH-RATES IN KENSINGTON AND WHITECHAPEL, 1891

Birth-rate.	Legitimate.			Illegitimate.		
	Kensington	Whitechapel.	Excess in Whitechapel.	Kensington.	Whitechapel.	Excess in Whitechapel.
(1)	(2)	(3)	(4)	(5)	(6)	(7)
			Per cent.			Per cent.
A Per thousand of population....	21 8	39 9	83	1.2	1.3	6
B Per thousand of women, aged 15–44 years... .	61.6	172 1	177	3.4	5.4	62
C Per thousand married women, aged 15–44 years	215 4	328.3	53			
D Per thousand, unmarried women, aged 15–44 years.	......	......	...	4.7	11.4	136

We see from this table that on the basis of married women of child-bearing age the birth-rate in the industrial district of Whitechapel was only 53 per cent greater than in the fashionable district of Kensington. On the basis of the general birth-rate or the rate computed for all women of child-bearing age the difference between the two districts would have been said to be much greater. In Kensington there were many unmarried servants. The illegitimate birth-rate computed on the basis of total population was only 6 per cent greater in Whitechapel than in Kensington, but on the basis of unmarried women of child-bearing age it was 136 per cent greater. This is an excellent example of the necessity of considering specific rates in the study of illegitimacy. Fallacious conclusions in regard to the relative morality of different nationalities, of urban and rural districts, of different states and cities have resulted from failure to take the proper ratios as a basis of study.

TABLE 50

MARRIAGE-RATE, MASSACHUSETTS

Year.	Persons married per 1000 population.	Year.	Persons married per 1000 population.
1900	17.4	1910	18.2
1901	17.3	1911	18.6
1902	17.5	1912	17.6
1903	17 9	1913	17.6
1904	16 9	1914	17.9
1905	18.1	1915	17 0
1906	19.5	1916	18 2
1907	20 1	1917	19 8
1908	17 3	1918	14.9
1909	16.2	1919	17 9
		1920	19.7

Marriage-rates. — The marriage rate is found by dividing the *number of persons* married in a year by the estimated mid-year population, expressed in thousands. The wedding-rate would be one-half of the marriage-rate. In some places this wedding-rate is called the marriage-rate, but this is not according to present-day practice. To prevent misunderstanding it is a good plan to use the expression "persons married per 1000 population."

The whole subject of nuptuality offers an interesting field for the application of the principles of statistics but will not be taken up in this book.

Divorce-rates. — Similarly the divorce rate is found by dividing the number of persons divorced in a year by the mid-year population.

Divorce in the United States is becoming more and more important as a social problem. The conditions are different in different states. In Massachusetts the data, obtained originally from court records, are published in the State Registration Report. The following figures are from the report of 1914.

The divorce-rate, based on an average for five years of which the census year was the median, has increased as follows.

TABLE 51

DIVORCE-RATE, MASSACHUSETTS

By five year periods

Median year.	Average rate per 100,000 population.	Average per 100,000 of married population
(1)	(2)	(3)
1880	30	....
1890	32	86
1900	47	123
1905	58	153
1910	56	146
1915	62	156
1920[1]	95	.. .

[1] This year only.

The relative number of divorces granted to wives is larger than the number granted to husbands. At present the ratio is in round numbers 7: 3.

The percentage distribution of divorces according to cause has been as follows:

TABLE 52

CAUSES OF DIVORCE, MASSACHUSETTS, 1900 to 1920

Cause.	Percentage.	
	Granted to husband	Granted to wife
(1)	(2)	(3)
	Per cent.	Per cent.
Deserton	63 3	42 0
Adultery	26 0	8 2
Cruel and abusive treatment	3 7	31.7
Intoxication	5 7	12 7
Nullity of marriage	1 1	0 6
Impotency	0 2	0 3
Neglect to provide	[1]	4 2
Imprisonment	[1]	0 3
Total	100 0%	100.0%

[1] Less than 0 1 per cent.

About four out of every five applications for divorce in Massachusetts are granted. About nine out of ten are not contested.

The distribution of divorces according to the duration of marriage is interesting. In 1920 the average duration of the marriage at the time application for divorce was made 10.7 years. The 4373 applications were distributed as follows:

TABLE 53

DURATION OF MARRIAGES ENDING IN DIVORCE

Duration of marriage.	Per cent of applications.
(1)	(2)
0– 6 months	1.0
6–11 "	1.1
1–4 years	21.2
5–9 "	31.5
10–19	32.8
20–29	9 8
30	2 6
Total.	100.0

In discussions of the divorce problem comparison is sometimes made between marriage-rates and divorce-rates. This is not a logical comparison. Why? The student must begin to answer such questions as this on the basis of his own reasoning.

The U. S. Bureau of the Census has estimated the probability of divorce[1] as not less than 1 in 16, and probably 1 in 12. This figure was based on the statistics of 1900, and means that one marriage in every 16 would probably be ended by divorce instead of continuing until "death do us part."

[1] Marriage and Divorce, 1867–1906, Vol. I, pp. 23, 24.

This general figure must not be taken too seriously, as it includes all classes of people living under many different conditions and represents past rather than present conditions.

Divorce statistics ought to be studied *specifically*, just as much as births and deaths.

Natural rate of increase. — The difference between the birth-rate and the death-rate gives the natural rate of increase (or decrease) in population per 1000 inhabitants. In the absence of immigration and emigration, and if the data are correct, the excess of births over deaths will correspond with the increase of population as revealed by the census counts. This may be illustrated by the statistics of Sweden from 1750 to 1900.

TABLE 54
INCREASE OF POPULATION IN SWEDEN

Year.	Population at end of given year (thousands).	Per 1000 of population at middle of period.		
		Increase as shown by census.	Excess of births over deaths	Emigration (computed from last two columns).
(1)	(2)	(3)	(4)	(5)
1750	1781	8.89	8 89	0.00
1760	1925	7 76	8.43	0 67
1770	2043	5.92	6.60	0 68
1780	2118	3.71	4 14	0.43
1790	2188	3 22	4.03	0 81
1800	2347	6.99	7 96	0 97
1810	2396	2.04	2 63	0 59
1820	2584	7 60	7.52	−0.08
1830	2888	11 02	11 00	−0.02
1840	3139	8 32	8 69	0.37
1850	3482	10 39	10.51	0 12
1860	3860	10.36	11 10	0 74
1870	4169	7 57	11 24	3 67
1880	4566	9 05	12 21	3 16
1890	4785	4 69	12 12	7 43
1900	5136	7.13	10.78	3 65
1910	5522	8 40	10 62	2 22

The figures in the last column show that there was very little emigration before 1870, but that since then the losses by emigration have been considerable. It is quite likely, however, that some of the early birth-rates were not as accurate as the more recent ones.

Comparison of general rates. — The object of computing gross death-rates is to enable us to compare the general mortality in places of different size and of different years in the same place; and yet, as will be demonstrated in the next chapter, such comparisons are very apt to be misleading unless the percentage composition of the population remains substantially constant in all the places and in all the years which are compared. One naturally asks, "Why, if such is the case, should we compute it at all?" The answer is that in a general and crude way the gross rate does show differences in the mortality of different places, and that in any given place the composition of the population changes slowly from year to year. Large differences in general death-rates may be significant, but small differences are usually not significant.

What is true of general death-rates is also true of birth-rates and marriage-rates. Far too much attention in studies of vital statistics is given to comparisons of general rates. Such comparisons are likely to be superficial and sterile of results. Nevertheless one should have a general appreciation of the changes which have taken place in birth-rates and death-rates throughout the world during the last fifty years. A few examples will be given, but the reader should consult more extended works on the subject and compile for himself tables of rates taken from official reports.

Marriage-rates, birth-rates and death-rates in Sweden. — One of the longest records of birth-rates, marriage-rates and death-rates is that of Sweden. Table 55 shows these

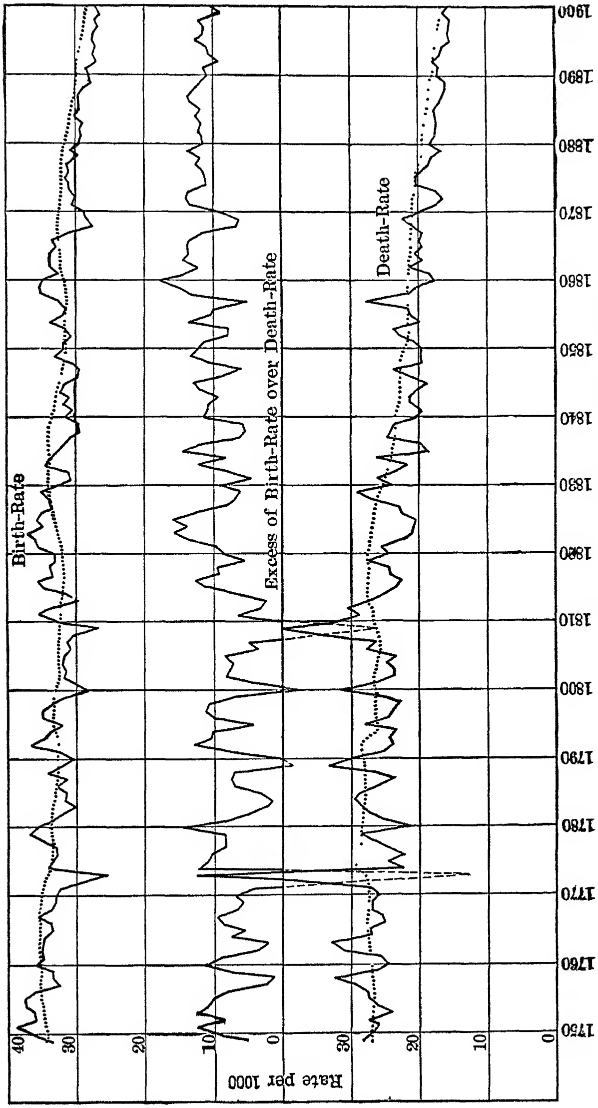


FIG. 63. — Vital Statistics of Sweden: 1750 to 1900.

rates from 1749 to 1900. The death-rates and birth-rates are also shown in Fig. 63. It will be seen that the birth-rate has had a general downward trend for a long time, but especially during the last fifty years. The death-rate has fallen more than the birth-rate so that the natural increase has risen. Of course, there have been fluctuations and some very abnormal rates will be found. As one would naturally expect the birth-rate has fluctuated synchronously with the marriage-rate. At intervals great epidemics have occurred which carried the death-rate far above the birth-rate. As a statistical series this diagram is deserving of careful study. The dotted line shows the "moving average" referred to in Chapter II.

TABLE 55

MARRIAGE-RATES, BIRTH-RATES, AND DEATH-RATES

Sweden, 1749-1900 (After Sundbärg)

Year.	Marriage-rate	Birth-rate.	Death-rate.	Natural increase	Year	Marriage-rate	Birth-rate	Death-rate.	Natural increase.
(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)
1749	17 10	33.82	28.13	5 69					
1750	18.48	36 40	28 83	9 57	1780	17 06	35 70	21 74	13 96
1751	18 54	38 63	26.18	12 45	1781	14 66	33 46	25 55	7 91
1752	18 52	35 91	27 34	8 57	1782	15 36	32 05	27 26	4 79
1753	17 42	36 12	24 03	12 09	1783	15 98	30 33	28 11	2 22
1754	18 90	37 22	26 33	10 89	1784	14 96	31 53	29 75	1 78
1755	18.32	37 52	27.38	10.14	1785	15 64	31 43	28.30	3 13
1756	17 00	36 12	27.66	8 46	1786	16 04	32 89	25 94	6.95
1757	15 94	32 61	29 92	2 69	1787	15 90	31 47	23 95	7 52
1758	16 14	33 42	32 37	1 05	1788	15 78	33 87	26.68	7 19
1759	19 50	33 62	26 27	7.35	1789	15 86	32 01	33 13	-1.12
1760	19 52	35 70	24 78	10.92	1790	16 50	30 48	30 43	0 05
1761	18 88	34 82	25 80	9 02	1791	21 68	32.63	25 49	7 14
1762	17 92	35 08	31.22	3 86	1792	20 02	36 58	23.90	12 68
1763	17 28	34 98	32 90	2.08	1793	17 80	34 39	24 27	10 12
1764	17.58	34 70	27 24	7.46	1794	16 36	33.79	23 60	10.19
1765	16 30	33 41	27.68	5 73	1795	15 18	32 04	27.94	4.10
1766	16 54	35 36	25 06	10 30	1796	17.24	34.68	24 65	10 03
1767	16 54	35.36	25 63	9 73	1797	16 88	34.77	23.81	10 96
1768	16 92	33 61	27 17	6 44	1798	16 58	33 68	23 08	10 60
1769	16.26	33.06	27.15	5 91	1799	14 70	32.02	25.18	6.84
1770	16.24	32 98	26.06	6 92	1800	14.90	28 72	31.43	0.9
1771	15.52	32 24	27.77	4 47	1801	14.50	30 04	26.08	3 96
1772	13.64	28 89	37 41	-8 52	1802	15.66	31 72	23.71	8.01
1773	15.52	25.52	52 45	-26 93	1803	16 38	31 36	23 77	7.59
1774	8 77	34.45	22 36	12.09	1804	16.14	31.90	24 87	7.03
1775	18 90	35 63	24 84	10.79	1805	16.74	31 73	23.48	8 25
1776	18 02	32 92	22 50	10 42	1806	16 08	30 75	27.51	3.24
1777	18.14	33 03	24 93	8.12	1807	16 40	31.16	26 22	5.94
1778	18 10	34 82	26.65	8.17	1808	16 24	30 39	34 85	5 54
1779	17.34	36 70	28 50	8 20	1809	15 62	26.67	40 04	13.37

TABLE 55

MARRIAGE-RATES, BIRTH-RATES, AND DEATH-RATES

Sweden, 1749-1900 (After Sundbärg)

Year.	Marriage-rate.	Birth-rate	Death-rate.	Natural increase.	Year	Marriage-rate.	Birth-rate	Death-rate.	Natural increase.
(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)
1810	21 52	32 95	31 57	1 38	1840	14 14	31 43	20 35	11.08
1811	21 32	35 30	28 81	6 49	1841	14 34	30 33	19 42	10 91
1812	18 26	33 57	30 27	3 30	1842	14 22	31 65	21 06	10 59
1813	15 48	29 74	27 37	2 37	1843	14 38	30 78	21 45	9 33
1814	15 04	31 19	25 07	6 12	1844	14 88	32 15	20 27	11 88
1815	19 22	34 77	23 59	11 18	1845	14 58	31 45	18 83	12.62
1816	19 60	35 32	22 66	12 66	1846	13 80	29 94	21.83	8 11
1817	16 68	33 40	24 25	9 15	1847	13 64	29 58	23 69	5 89
1818	16 92	33 83	24 37	9 46	1848	14 64	30 33	19 68	10 65
1819	16 28	32 99	27 36	5 63	1849	15 66	32 84	19.84	13 00
1820	16 88	32 97	24 46	8 51	1850	15 18	31.89	19 79	12 10
1821	17 62	35 44	25 57	9 87	1851	14.72	31 74	20 72	11 02
1822	18.58	35 88	22 59	13 29	1852	13 68	30 69	22 70	7 99
1823	17 98	36 83	21 02	15 81	1853	14 40	31 37	23 66	7 71
1824	17 66	34 56	20 77	13.79	1854	15 38	33 50	19 76	13 74
1825	17 20	36 49	20 54	15 95	1855	15 04	31 75	21 45	10 30
1826	16 16	34 84	22 61	12 23	1856	14 88	31 47	21 77	9 70
1827	14 44	31 30	23 05	8 25	1857	15 50	32 43	27 58	4 85
1828	15 82	33 61	26 74	6 87	1858	16 22	34 77	21.69	13 08
1829	15 82	34.85	28 97	5 88	1859	16 56	34 99	20 13	14 86
1830	15 46	32 91	24 08	8 83	1860	15 60	34 83	17 65	17 18
1831	13 80	30 49	26 00	4 49	1861	14 54	32 57	18 47	14 10
1832	14 38	30 86	23 38	7 48	1862	14 52	33 38	21 40	11 98
1833	15 66	34 11	21 74	12 37	1863	14 52	33 62	19 33	14 29
1834	16 02	33 74	25 68	8 06	1864	13 96	33.61	20 25	13 36
1835	15 00	32 67	18 55	14 12	1865	14.14	32 81	19.36	13 45
1836	14 34	31 84	19 97	11 87	1866	13 44	33 11	19.98	13 13
1837	13 80	30 84	24 65	6 19	1867	12 18	30 83	19 64	11 19
1838	12.18	29 37	24.10	5 27	1868	10 92	27 47	20 98	6 49
1839	13 54	29 49	23 56	5.93	1869	11 28	28.25	22 27	5.98

TABLE 55

MARRIAGE-RATES, BIRTH-RATES, AND DEATH-RATES

Sweden, 1749-1900 (After Sundbärg)

Year.	Marriage-rate.	Birth-rate	Death-rate	Natural increase	Year.	Marriage rate	Birth-rate.	Death-rate	Natural increase.
(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)
1870	12 04	28 78	19.80	8.98	1900	12 30	27 00	16.84	10 16
1871	12 98	30 42	17 21	13.21	1901	12 14	27 03	16 05	10 98
1872	13 86	30 04	16 28	13.76	1902	11 92	26 48	15.37	11 11
1873	14 62	30 80	17.20	13.60	1903	11 56	25 70	15.09	10.61
1874	14 54	30 85	20 32	10.53	1904	11 70	25.75	15.29	10 46
1875	14 10	31 17	20 27	10 90	1905	11.70	25 66	15 62	10.04
1876	14 16	30.84	19 59	11.25	1906	12 26	25 70	14 37	11 33
1877	13 66	31 07	18.66	12.41	1907	12 42	25 53	14 59	10.94
1878	12 94	29 83	18 06	11.77	1908	12.24	25 70	14 91	10 79
1879	12 58	30 52	16 94	13.58	1909	11.94	25 58	13 67	11.91
1880	12 64	29 36	18.10	11.26	1910	12 06	24.66	14 04	10.62
1881	12 38	29.07	17 58	11.39	1911	11.76	23 99	13 80	10.19
1882	12 66	29 35	17 35	12.00	1912	11.98	23 80	14 19	9.61
1883	12 86	28.94	17 31	11 63	1913	11 86	23 16	13 65	9.51
1884	12 06	30.01	17.53	12.48	1914	11.64	22.88	13 84	9.04
1885	13 26	29 44	17.75	11.69	1915	11 66	21 59	14 67	6.92
1886	12.82	29 76	16.61	13.15	1916	12.22	21 22	13.56	7 66
1887	12 50	29.66	16 13	13.53	1917	12 30	20 91	13 39	7.52
1888	11 84	28 78	15 99	12.79	1918	13.30	20 27	17 94	2.33[1]
1889	11 98	27.74	15.99	11.75	1919	13 84	19.64	14.45	5.19
1890	11 98	27 95	17.12	10 83	1920	14 58	23.57	13.29	10.28
1891	11 66	28 27	16 81	11 46					
1892	11 38	26 98	17.88	9 10					
1893	11 30	27.36	16.83	10.53					
1894	11 48	27.10	16 38	10 72					
1895	11.74	27.49	15 19	12 30					
1896	11 90	27.18	15.64	11 54					
1897	12 12	26 67	15 35	11 32					
1898	12 28	27 11	15 08	12 03					
1899	12.48	26 35	17.65	8 70					

[1] Year of influenza epidemic.

Downward trend in birth-rates and death-rates. — For nearly half a century there has been a general downward trend in the birth-rates and death-rates of almost all civilized countries. There is space here for only a few figures which represent averages for quinquennial periods. They are taken from the reports of the Registrar-General of England.

TABLE 56

CHRONOLOGICAL CHANGES IN VITAL RATES

Country.	Quinquennial averages.						
	1881–5	1886–90	1891–5	1896–00	1901–5	1906–10	1911–15
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
			Birth-rates.				
England and Wales	33 5	31 4	30 5	29 3	28 1	26 3	23 6
Germany	37 0	36.5	36 3	36 0	34 3	32 7	....
France	24 7	23 1	22 3	21 9	21 2	19 9	....
Hungary	44 6	43 7	41 7	39.4	37.2	37 0	....
			Death-rates				
England and Wales	19 4	18 9	18 7	17 7	16 0	14 7	14 3
Germany	25 3	24 4	23.3	21.2	19 9	17 5	....
France	22 2	22 0	22 3	20.7	19 6	19 2	....
Hungary	33 1	32 1	31 8	27 9	26.2	25 0	....
			Rates of natural increase.				
England and Wales	14 1	12 5	11.8	11.6	12.1	11 6	9.3
Germany	11 7	12.1	13.0	14.8	14.4	15 2	....
France	2 5	1 1	0.0	1.2	1.6	0.7	....
Hungary	11.5	11.6	9 9	11.5	11.0	12 0	....

In most countries the natural rate of increase tends to lie between the limits of 8 and 14 per 1000, *i.e.*, between 0.8 and 1.4 per cent, but sometimes it runs above 1.4 per cent or below 0.8 per cent per year. France is an example of an extremely low rate of natural increase. In Germany both the birth-rates and death-rates have been higher than in England. In Hungary both rates have been much higher than in Germany, yet the rate of natural increase has been lower. The student should seek to explain all of these facts.

Since the Great War the birth-rates in many countries have been lower and the death-rates higher than before.

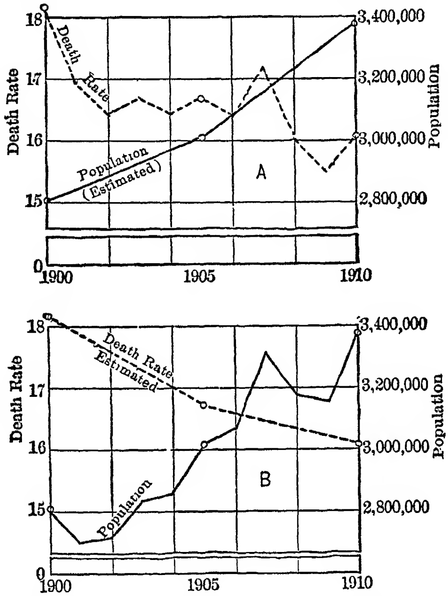


FIG. 64. — Estimated Death-rates and Populations, Massachusetts, 1900–1910.

Variations due to population estimates. — Some of the variations in the general death-rates from year to year are due to the use of incorrect population estimates. The following comparison is interesting.

Fig. 64 shows the populations and death-rates for the state of Massachusetts from 1900 to 1910, based on the following data:[1]

[1] Registration Report, 1914, p. 176.

TABLE 57

DEATH-RATES: MASSACHUSETTS

Year	Population.	Deaths	Death-rates.
(1)	(2)	(3)	(4)
1900	**2,805,346** (census)	51,156	18 2
1901	2,849,047	48,275	16 9
1902	2,889,386	47,491	16 4
1903	2,929,725	49,054	16 7
1904	2,970,064	48,482	16 3
1905	**3,015,872** (census)	50,486	16 7
1906	3,089,029	50,624	16 4
1907	3,162,186	54,234	17 2
1908	3,235,343	51,788	16 0
1909	3,308,500	51,236	15 5
1910	**3,380,151** (census)	54,407	16 1

The upper diagram shows the estimated population as a uniform change from 1900 to 1905 and again from 1905 to 1910. The death-rates computed from the actual deaths and estimated populations are seen to vary irregularly. But suppose we assume that the changes in death-rates between 1900 and 1905 and 1905 and 1910 are uniform. Then we can compute the changes in population from these estimated rates and the actual deaths. The results are shown in the lower diagram. Do these irregular fluctuations seem to be reasonable?

There is no way of telling exactly how much of the increase or decrease in the general death-rate is due to actual increase in mortality and how much to error in the estimated population. Both factors are involved.

Birth-rates and death-rates in Massachusetts. — Fig. 65 shows the annual variations in birth-rates and death-rates from 1850 to 1920. The stars indicate the so-called panic years, or years of business depression. The tendency has been for the marriage-rate and the birth-rate to fall for a number of years after a period of depression. Since

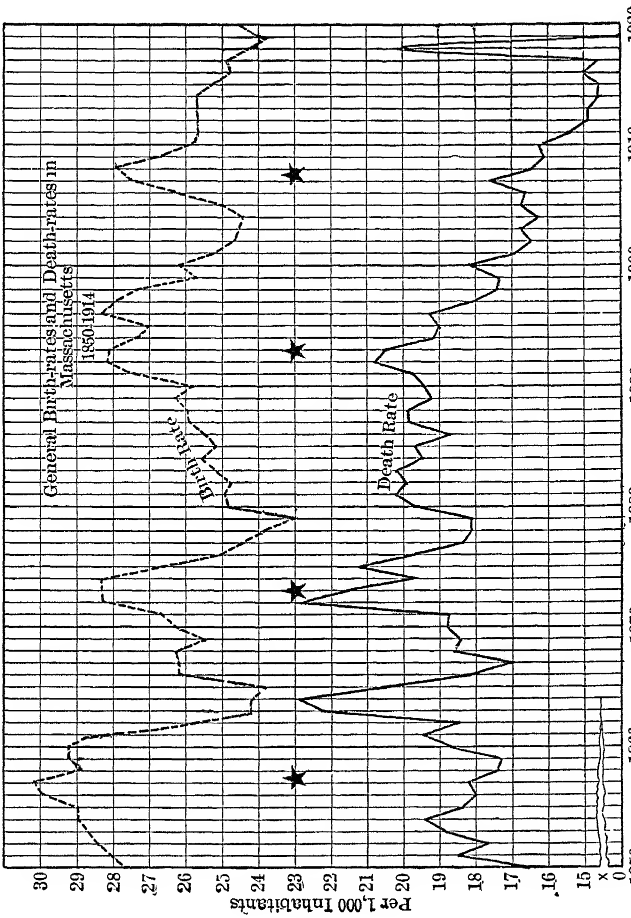


FIG. 65. — Birth-rates and Death-rates in Massachusetts. The stars show the "Panic Years."

1892 the death-rate has decreased considerably. The general synchronism between the birth-rate and the death-rate should be noticed, — and also the numerous exceptions to the rule. The increased death-rate in 1918 due to the epidemic of influenza is striking.

In recent years there has been a marked tendency towards uniformity in the death-rate, not only in the state as a whole from year to year, but among the subdivisions of the state in any given year.

The fluctuations from year to year are due in part to incorrect estimates of population.

Monthly death-rates in Massachusetts. — The general death-rate is not constant throughout the year, but varies seasonally. There are several ways in which this may be shown. The following figures are for the state of Massachusetts for the year 1920.

TABLE 58

MONTHLY DEATH-RATES: MASSACHUSETTS, 1920

Month.	Rate	Per cent of annual rate.
(1)	(2)	(3)
Jan.	15.69	113
Feb.	24.90	180
Mar.	16.65	120
Apr.	14.35	104
May	13.23	96
June	11.33	82
July	10.36	74
Aug.	11.15	80
Sept.	11.82	85
Oct.	11.97	86
Nov.	12.39	89
Dec.	13.14	95
Year	13.90	100

Monthly rates vary considerably from year to year in the same place and are different for different places. Climatic conditions have an influence on these short term rates. The chance occurrence of communicable diseases also has its effect. Weekly rates fluctuate even more widely than monthly rates, and daily rates *à fortiori.*

The student should compute and study monthly rates for places where the climatic conditions are different.

Marriage-rates in Massachusetts. — Marriage-rates rise and fall periodically. The rate is influenced by social and economic conditions, by the age distribution of the population, the ratio of the sexes at marriageable age, by nationality, and by many causes. There has been no steady downward trend in the marriage-rate as in the case of the death-rate and birth-rate. There is, however, a seasonal variation. June and October are the most popular months for weddings.

In 1920 the Massachusetts marriage-rate for the year was 19.7; in June it was 38.8, in October, 26.4, but in March only 7.4. There were five times as many weddings in June as in March.

Since 1870 the median marriage-rate in Massachusetts has been 18.0. After the panic of 1873 the annual rates for several years ranged between 15 and 16.5, and after other periods of business depression they have been below 17. The highest annual rate in nearly fifty years was during 1871 and 1872, when it was 21.1 per thousand.

The published statistics of marriages generally include tables classified according to the age and nativity of the bride and groom; the number of the marriage (whether first, second, third, etc.); and the previous state of the persons wed (whether bachelors, maids, widowers, or widows).

Divorce-rate in Massachusetts. — In 1920 the number of persons divorced was 1.89 per 1000 population; in 1915 the rate was 1.22; in 1910, 1.15; in 1890, 0.58; in 1870, 0.52.

Limited use of general death-rates (gross rates). — General death-rates are composite figures. They cover the entire population, both sexes, all ages and nationalities, all occupations, all causes of death, while the estimates of population are often inaccurate. Fluctuations from year to year depend in part on the size of the population, in part upon the composition of the population, as well as upon causes of death. Under these conditions it is evident that they cannot be safely used as an index of mortality conditions in different places and for long periods of time in any one place.

A general death-rate, or gross death-rate, is of little use until it has been analyzed.

The " total solids " in a water analysis gives the chemist almost no idea of the quality of the water: it is necessary to separate the " solids " into their constituent parts. In the same way a general death-rate must be broken up into its constituent parts. At the present time the analysis of death-rates is practiced but little. Death-rate analysis today is in about the same condition that water analysis was in fifty years ago.

The necessary analysis cannot be made until the important subject of specific death-rates has been considered in the next chapter.

The birth-death ratio. — Dr. Raymond Pearl[1] has given the name " vital index " to the ratio between births and deaths. If 100 births ÷ deaths exceeds 100 the population is growing and is biologically healthy; but if the ratio is less than 100 the population is decadent. Valuable use can be made of this ratio, especially in studying the biological conditions of the component parts of a population. For example, in New York State in 1918 the vital index for the native whites, i.e. $\frac{\text{100 (Births of whites of native parents)}}{\text{Deaths of all native whites}}$

[1] loc. cit.

was only 82.1; but the vital index for the foreign-born, i.e. $\frac{100\ (\text{Births of whites, both parents foreign})}{\text{Deaths of foreign-born whites}}$ was 176.3. In order to use this index to the best advantage it is necessary to apply it to specific classes or groups of the population.

Taking the entire registration area of the United States, Pearl finds the following indices.

TABLE 59

VITAL INDICES, 1918

	Native whites	Foreign born whites.	Negroes.
Total population ..	118.8	151.8	93.7
Urban....	93.2	166.9	66.8
Rural	144.8	118.8	118.4

These figures speak for themselves. The data for the different parts of the country are striking, as the following figures for 1917 show.

TABLE 60

VITAL INDICES, 1917

	Massachusetts.			Vermont.		
	Native whites.	Foreign born whites	Negroes	Native whites	Foreign born whites.	Negroes
Total	88.5	239.6	113.3	114.4	137.3	116.7
Urban .	92.1	246.5	111.3	114.7	147.8	100.0
Rural .	77.4	207.4	128.4	114.3	134.7	125.0

	Wisconsin.			North Carolina.		
	Native whites.	Foreign born whites	Negroes.	Native whites	Foreign born whites.	Negroes.
Total .	231.5	89.8	60.4	255.4	106.3	173.1
Urban .	178.4	142.2	75.0	148.0	60.9	78.1
Rural ...	266.0	57.6	37.1	266.8	160.3	190.3

In New England and New York the native population is not reproducing itself; and practically everywhere the foreign-born population is showing a higher degree of vitality than the native-born. There are no data available to show the vital index for the "old New England stock," but it is probably much lower than the figures given above for Massachusetts native born. Pearl has made an interesting study of race-mixing in the United States, — that is, the mating of foreign and native born persons who produce offspring. This mixing takes place to a greater extent among the American-born than among the foreign-born. He says that to bring about Americanization what is necessary is to break up the segregation of foreigners. "Give the foreign elements a chance to meet and really know the native population and the melting pot promptly begins to seethe and bubble."

The ideal death-rate. — Is there such a thing as an ideal death-rate? At present our general death-rates are falling. They cannot continue to fall forever, for man is mortal and all must die? A large part of the decrease in the death-rate can be traced to sanitary, hygienic and medical improvements. Another part may be due to a lowering birth-rate following a relatively high birth-rate, or in other words to an increasing ratio of persons in the young and middle-aged groups. This condition will not continue permanently. In due course the young will become middle aged and the middle aged will become old, the excess of population will enter those age-groups where the specific death-rates are high and this will cause the general death-rate to rise. Or the birth-rate will rise and temporarily this will raise the general death-rate.

Unless public health officials learn how to view general death-rates in a proper light — a good way being not to view them at all — they may be surprised and discouraged some day to find that the death-rate is rising.

The Great War in a most horrible and pitiful way cut out a large number of males in the middle-aged groups in many countries. Temporarily this will increase the general death-rate. On the other hand these young men will not live to enter the old-age groups where the specific death-rates are high. What effect will this have on the future trend of the death-rate? What effect will it have on the birth-rate?

Perhaps it may be for the best interest of the race that the general death-rate be higher than it now is. This would be the case if there should be more babies and more grandfathers and grandmothers. To answer the question as to what is the lowest practicable death-rate we must first decide what is an ideal distribution of population as to age and sex, and then consider what diseases at the different ages we can reasonably expect to eliminate. It is an interesting problem for thought and discussion, but one upon which no two people are likely to agree.

EXERCISES AND QUESTIONS

1. Plot the general death-rates of Massachusetts by years from 1850 to date. Connect the points with straight lines. Then draw straight lines connecting the death-rates for the years divisible by ten. Why is the resulting curve so regular? Connect the points for years ending in 9. Why is the resulting curve so irregular?

2. Compare the published statistics for tuberculosis as given by local, state and federal authorities. Explain the differences. [See Am. J. P. H., May 1913, p. 431.]

3. Compute the following death-rates, carrying the results only as far as accuracy warrants.

Population	Deaths per year
5,461,200	70,210
261,500	2,913
35,000	421
5,260	98
897	17

4. How does the marriage-rate ordinarily compare with the ratio of marriages to persons eligible to marriage (bachelors, spinsters, widowers, widows and divorced persons, all of marriageable age)? [Newsholme's "Vital Statistics," p. 58.]

5. How do the marriage-rates in cities compare with those in rural districts?

6. Is the marriage-rate a reliable "barometer of prosperity," as Dr. Farr called it?

7. What effect has war on the marriage-rate?

8. What proportion of marriages are remarriages?

9. Are remarriages more common among widowers or widows?

10. Prepare a table showing the marriage state (single, married, widowed, divorced) of the population of some civil division for each sex and for different age-groups above age fifteen. [Consult census reports.]

11. At what ages do people in different social positions marry?

12. What changes, if any, have taken place in the age of marriage among people of different social position during recent years?

13. How do the general birth-rates for urban and rural districts compare with each other?

14. How do the birth-rates for urban and rural districts compare with each other if based on the number of married women of child-bearing age?

15. What relation is there between birth-rates based on married women of child-bearing age and the social position of these women?

16. What relation is there between the birth-rate thus computed and the age of marriage?

17. What influence has war on the general birth-rate?

18. What influence has national prosperity on fecundity?

19. How do the general birth-rates compare for different political countries, such as England, Ireland, France, Germany, Austria, Belgium, etc.

20. How do the birth-rates for different nationalities in the United States compare with each other?

21. How does the birth-rate for the Irish in Ireland compare with that of the Irish in Massachusetts?

22. How do the birth-rates among Catholics compare with that among Protestants? Consult the statistics of Canada, especially the provinces of Ontario and Quebec.

23. What is the ratio of males to females among births?

24. What is the ratio of males to females among still-births?

25. What is the ratio of males to females among illegitimate births?

CHAPTER VIII

SPECIFIC DEATH-RATES

Although general death-rates have their uses, something more is needed if statistics of mortality are to be used to their best advantage. The tendencies of human beings to die are not constant; diseases differ in their fatality; persons of different age differ in susceptibility to disease; sex, nationality, connubial condition are likewise variable factors. One cannot properly use mortality statistics in public health work without taking these factors into account, at least without considering the most important of them. This brings us to a consideration of *specific death-rates.* General death-rates are ratios between the entire population of a given place and all deaths which occur in a year. We may restrict these rates in several ways.

Restrictions of death-rates. — We may consider a shorter period than a year, and compute the rate for a month or a week and thus obtain a partial rate or a short-term rate as described in the previous chapter. This, however, is not usually classed as a specific rate.

We may restrict the computation to a special class or group of the population; that is, we may take into account only males or only females and compute the death-rate for them alone. These would be specific death-rates by sex. We may consider each age-group by itself and find the death-rate for it alone. This would be to compute specific death-rates by age-groups. Or we may take only persons of the same nationality or occupation and compute specific death-rates for them.

Again we may consider separately the different causes of death, and compute specific death-rates for tuberculosis, for scarlet fever, or for cancer.

Finally we may consider particular diseases and at the same time restrict the computation to certain classes or groups of people; thus we may compute the "typhoid fever death-rate for males in age group 15–19 years."

It has been suggested that these various modes of restriction might be designated by such expressions as "special" death-rates, "particular" rates, "limited" rates, etc., but apparently the common expression "specific" death-rate serves every useful purpose.

It is the purpose of the present chapter to describe the methods of computing specific rates and to call attention to their importance. It is not too much to say that *an understanding of specific rates is the key to the interpretation of vital statistics.* Failure to appreciate the important influences of age is alone responsible for scores of fallacious conclusions derived from tables of vital statistics.

Age. — The span of human life has been divided into age periods in many different ways. Shakespeare[1] vividly describes the seven ages of man.

> *Jaques:* All the world's a stage,
> And all the men and women merely players:
> They have their exits and their entrances;
> And each man in his time plays many parts,
> His acts being seven ages. At first the infant,
> Mewling and puking in the nurse's arms;
> Then the whining school-boy, with his satchel
> And shining morning face, creeping like snail
> Unwillingly to school; and then the lover,
> Sighing like furnace, with a woeful ballad
> Made to his mistress' eyebrow; then a soldier,
> Full of strange oaths and bearded like the pard,

[1] Jaques in *As You Like It*, Act II, Scene VII.

Jealous in honour, sudden and quick in quarrel,
Seeking the bubble reputation
Even in the cannon's mouth; and then the justice,
In fair round belly with good capon lin'd,
With eyes severe and beard of formal cut,
Full of wise saws and modern instances;
And so he plays his part; the sixth age shifts
Into the lean and slipper'd pantaloon,
With spectacles on nose and pouch on side,
His youthful hose well sav'd, a world too wide
For his shrunk shank; and his big manly voice,
Turning again toward childish treble, pipes
And whistles in his sound; last scene of all,
That ends this strange eventful history,
Is second childishness and mere oblivion,
Sans teeth, sans eyes, sans taste, sans every thing.

Just where to draw the age lines between Shakespeare's seven ages is a most difficult matter and it would be hard to get any two people to agree. The divisions suggested in Fig. 66 are merely for provoking discussion.

Physiologically seven fairly distinct states may be recognized — the pre-natal state, infancy, childhood, youth (maidenhood), early manhood and manhood (child-bearing age and maturity), and finally old age, or senility. The age limits of the early groups are fairly well marked. The later groups are more indistinct. He would be a bold person who would undertake to establish an age limit for senility. Every one knows what was said about Dr. Osler when he attempted to do something of that sort. In Fig. 66 the biblical limit of "three score years and ten" has been used. The author believes that he may safely hide behind that. The division between childhood and youth in boys is perhaps not quite the same as the division between childhood and maidenhood in girls.

From the standpoint of environment there are several fairly distinct age periods. Infancy in this case means the

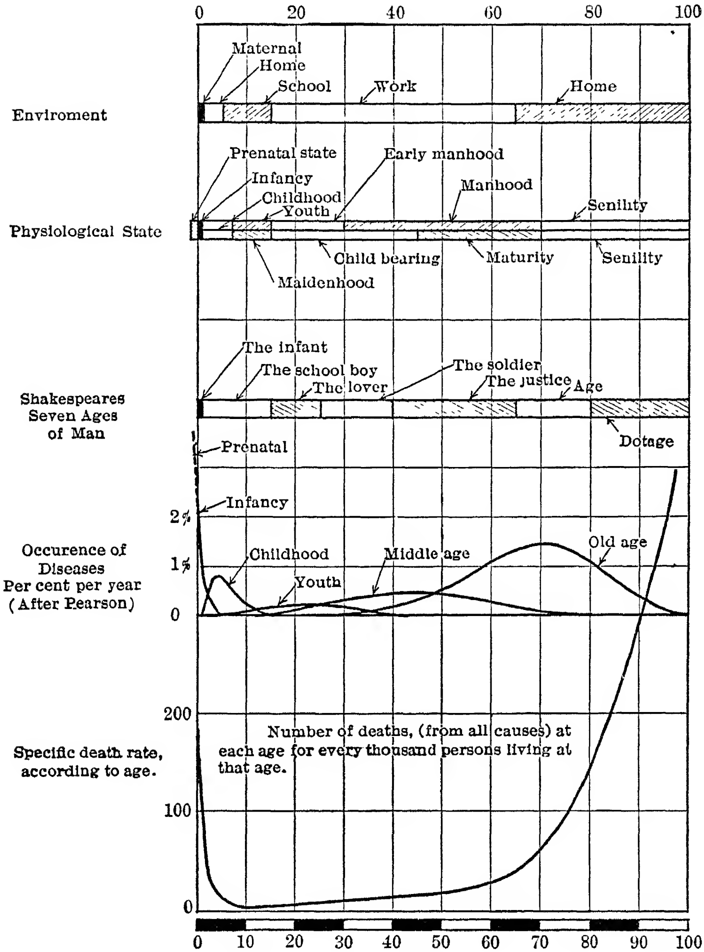


FIG. 66. — Ages of Man.

earliest period, in which the environment is maternal. It terminates when the child is weaned. Then follows the period of home environment. Later the school environment controls. After that the work place comes in as an important factor. Of course the home influence continues through life, and in the case of most women it predominates after the school age. Indeed after the school age the environment becomes complex.

Karl Pearson has analyzed the curve which shows the age distribution of deaths in an interesting way. He concludes that there are five groups of diseases, those of infancy, childhood, youth, middle age and old age. All of these extend over wide limits, but culminate at the ages shown in Fig. 66. One may die of an old age disease at thirty, or one may have a children's disease at forty. Endless complications exist in special cases, yet in the main the distinctions between the five classes of diseases are well known.

At the bottom of the diagram we see the curve which shows the specific death-rate in its characteristic variations through the span of life. This curve in its general form is the same for both sexes, for all nationalities, for all climates. There are differences, of course, but over all the other factors which influence death, age predominates. This curve, it should be observed, is based on deaths from all causes. It would not necessarily apply to particular diseases.

The student should study this curve of specific death-rates according to age until he can reproduce it with approximate accuracy from memory.

Vision of Mirza. — Those who do not enjoy studying statistics may appreciate the following paragraph taken from Addison's "Vision of Mirza."

"The bridge thou seest, said he, is *Human Life;* consider it attentively. Upon a more leisurely survey of it, I found that it consisted of *threescore and ten entire arches*, with several broken arches, which, added to those that were entire, made up the number *about an hundred*. As I was counting the arches, the Genius told me that this bridge consisted at first of a *thousand arches;* but that a great flood swept away the rest, and left the bridge in the ruinous condition I now beheld it. But tell me further, said he, what thou discoverest on it. I see multitudes of people passing over it, said I, and a black cloud hanging on each end of it. As I looked more attentively, I saw several of the passengers dropping through the bridge into the great tide that flowed underneath it: and upon further examination perceived that there were innumerable trap-doors that lay concealed in the bridge which the passengers no sooner trod upon, but they fell through them into the tide, and immediately disappeared. These hidden pit-falls were set very thick at the entrance of the bridge, so that throngs of people no sooner break through the cloud, but many of them fell into them. They grew *thinner towards the middle*, but multiplied and laid closer together towards the end of the arches that were entire. There were, indeed, persons, but their number was very small, that continued a kind of hobbling march of the broken arches, but fell through one after another, being quite tired and spent with so long a walk."

How to compute specific death-rates. — The specific death-rate for any age-group is found by dividing the number of deaths of persons whose ages lie within the group limits by the number of thousands of persons in the same group alive at mid-year. The computation is precisely the same as that for the general death-rate except that both deaths and population are confined to specific age-groups. If both quantities are known the process is merely arithmetical.

Example: — Given the following data for New South Wales, 1901 (Columns 1, 2, 3).

TABLE 61

Age-group.	Population.	Deaths.	Specific death-rate.
(1)	(2)	(3)	(4)
0–1	40,500	3,234	79 9
1–19	704,000	1,960	2 8
20–39	514,900	2,251	4 4
40–59	256,600	2,965	11 6
60–	89,800	5,400	60 1
Total	1,605,800	15,810	9.85

To find the specific death-rate for the age-group 1–19 years, divide the number of deaths in that group, *i.e.*, 1960 by 704, the number of thousands of population. The result is 2.8 per 1000. Similarly the specific death-rate for age-group 20–39 is 2251 ÷ 515 = 4.4 per 1000. The figures in Column 4 were thus computed. The total deaths divided by the total population, in thousands, gives the general death-rate, *i.e.*, 15810 ÷ 1605.8 = 9.85 per 1000.

If the number of deaths within the age-group is known but the population is unknown, it is necessary to estimate the population in the group. This can usually be done with sufficient accuracy from the data provided by the censuses. The methods of making these estimates both for censal and non-censal years has been already described. This may involve a redistribution of the population from those given in the census to those corresponding to the death statistics.

If the population in the group is known but the number of deaths is unknown the computation cannot be made with accuracy. It might be possible to redistribute the deaths into age-groups corresponding to the population, but

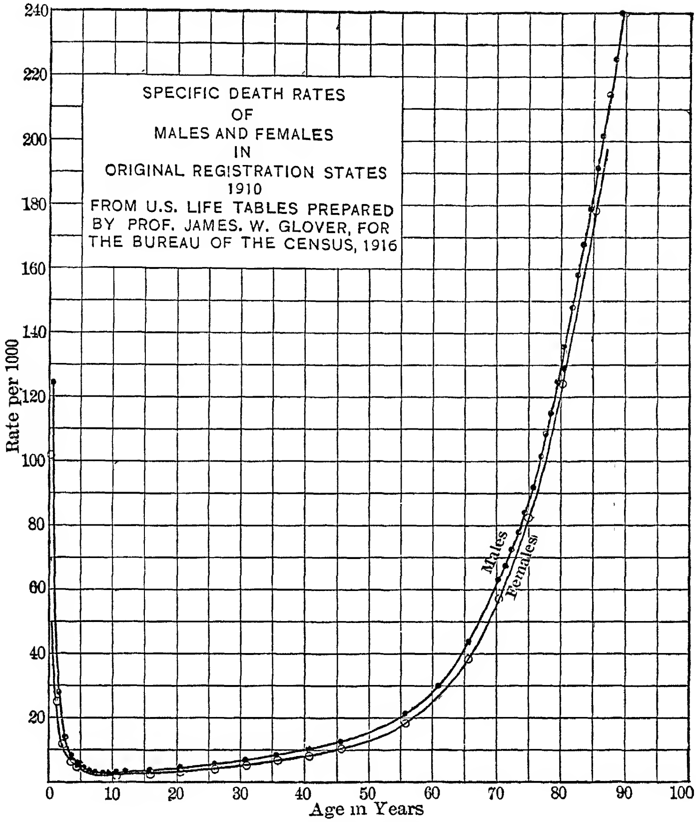


FIG. 67. — Specific Death-rates.

specific death-rates obtained in this way would in most cases be unreliable.

Specific death-rates by ages for males and females. — Looking at the two curves for the specific death-rates of males and females shown in Fig. **67** one would say at first that they were much alike, but that the rates at all ages were higher for males than for females. In a general way this is true, but a closer study shows that the differences are not the same for all ages. The table from which these curves were plotted gave data from which the following figures were obtained.

TABLE 62

PER CENT BY WHICH THE SPECIFIC DEATH-RATES FOR MALES EXCEEDED THOSE FOR FEMALES IN VARIOUS AGE INTERVALS

(Based on the original registration states; population in 1910, and deaths in 1909, 1910 and 1911).

Age interval	Per cent (approximate)	Age interval.	Per cent (approximate)
(1)	(2)	(3)	(4)
yr 0-1	20	yr 55-56	14
5-6	5	60-61	19
10-11	15	65-66	14
15-16	5	70-71	10
20-21	15	75-76	12
25-26	6	80-81	8
30-31	10	85-86	7
35-36	20	90-91	3
40-41	35	95-100	−2
45-46	27	100-101	3
50-51	23		

In infancy the death-rate for males exceeds that for females by 20 per cent. Between five and twenty-five years of age the differences vary considerably in successive years but average about 10 per cent.[1] Above age twenty-five the male death-rate begins to exceed the female death-rate by considerable amounts and this continues to the age of forty, when the excess is 35 per cent. After that it steadily decreases. In old age the two rates are much alike. It must be remembered that these figures are for a certain

[1] The error of population due to concentration on round numbers probably accounts for some of these differences.

limited area and for a short interval of time and for a particular composition of people with respect to nationality, birth-rate, and so on. They are to be regarded merely as illustrative of the differences between males and females. What are the reasons for the differences here shown?

Effect of marital condition on specific death-rates. — Students will find it interesting to compute specific death-rates for males and females according to their marital condition. It will be found that the rates for single men are considerably higher than for married men. Between thirty and forty years of age they may be nearly twice as high; at higher ages the percentage differences become less. The death-rates of single females are higher than those of married females except that during part of the child-bearing period, — say from twenty to forty-five, — the rates are higher for married women.

Professor Walter F. Willcox, of Cornell University, has computed the following specific death-rates for New York State, the cities of New York and Buffalo excluded, for 1909–1911, arranged by age-groups and by classes corresponding to marital condition, as follows:

TABLE 63

SPECIFIC DEATH-RATES ACCORDING TO AGE AND MARITAL CONDITIONS, NEW YORK, 1909-11

Age-group.	Males.			Females.		
	Single.	Married.	Widowed or divorced.	Single.	Married.	Widowed or divorced.
(1)	(2)	(3)	(4)	(5)	(6)	(7)
20–29	6.6	4 2	12 0	4 7	5 7	9 4
30–39	12 9	5 9	14 1	7 4	6 3	9.5
40–49	19 5	9 5	17 3	10 0	8 2	12.1
50–59	28 7	17 0	30 5	19 9	14 5	18 8
60–69	51.0	31 9	48 6	37 1	28 1	38 2
70–79	101 4	72 7	96 0	82 2	61 4	87 2
80–	204 2	205.1	315 7	279 8	194.8	269.8

Among the theories suggested in explanation of these differences is the effect of leading a better supervised and more restrained life among married persons, the better economic conditions of the married, the effect of marriage selection and the effect of the marriage relation itself.

Nationality and specific death-rates. — Specific death-rates for different ages and sexes are not the same for all nationalities. It is very difficult, however, to say how much of this is due to racial difference and how much is due to environmental conditions; that is, it is hard to separate the physiological from the social and economic factors. Practically, however, these factors must be considered together in discussing nationalities in the United States. We see these differences well marked between the negro and the white populations of the original registration states. The figures in Table 64, taken from Professor Glover's report, will show this.

The figures in this table are carried to an unnecessary degree of precision so far as this particular point is concerned and in the case of the advanced ages for negroes probably not even the whole numbers are accurate. The rate for male negroes is almost double that for male whites up to the age of sixty or thereabouts; above eighty the rate for negroes is lower than for whites. Substantially the same relations hold for white and colored females.

It should be noticed that in these various comparisons the effect of age is a factor which must never be left out of account.

TABLE 64

SPECIFIC DEATH-RATES FOR WHITE AND NEGRO MALES

United States, Original Registration States, 1910

Age interval	Rates per 1000	
	White	Negro
(1)	(2)	(3)
0–1	123.26	219.35
5–6	4.71	8.56
10–11	2.38	5.02
15–16	2.83	7.87
20–21	4.89	11.96
25–26	5.54	12.28
30–31	6.60	14.96
35–36	8.52	17.28
40–41	10.22	21.03
45–46	12.64	23.99
50–51	15.53	31.42
55–56	21.50	39.50
60–61	30.75	50.79
65–66	43.79	64.33
70–71	62.14	83.98
75–76	92.53	112.77
80–81	135.75	131.27
85–86	191.11	179.82
90–91	255.17	201.01
95–96	324.86	227.76
100–101	427.46	336.29

Effect of the age composition of a population on the death-rate. — It is evident also, from our acquired knowledge of specific death-rates, that the general death-rates of two places cannot be reasonably compared unless the age composition of the population is substantially the same in the two places. The following simple example will make this plain:

Two places, *A* and *B*, have the same total population, *i.e.*, 50,000; and they have the same specific death-rates at different ages. The ages of the people, however, differ as shown in the table. From these figures we may compute the general death-rate for each place.

TABLE 65

EFFECT OF AGE COMPOSITION OF POPULATION ON THE GENERAL DEATH-RATE

Age	Population		Specific death-rate per 1000	Computed deaths		Computed death-rates per 1000	
	A	*B*		*A*	*B*	*A*	*B*
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
0–4	10,000	20,000	25	250	500		
5–59	35,000	20,000	10	350	200		
60–79	5,000	10,000	60	300	600		
Total	50,000	50,000		900	1300	18	26

In *B*, a place with a large number of children and old people, the rate is 26 per 1000, while in *A*, a place with a large middle-aged population, the rate is only 18. This is, of course, an exaggerated case, but slight differences in age distribution make a greater difference in the general death-rate than one would suppose.

In 1899, according to a report of the U. S. Secretary of War, the annual death-rate of soldiers in the Philippines was 17.20, while the death-rate of Boston was 20.09, of Washington 20.74 and of San Francisco 19.41. The obvious inference was that the mortality in the army compared favorably with the mortalities of the cities mentioned. The facts unstated were that soldiers are picked men in a limited age-group while the cities contain a conglomerate population. A better comparison would have been one between the soldiers and males between 20 and 40 years of age in the United States, the usual death-rate for which is less than 10 per 1000. Hence the mortality among the troops in the Philippines was nearly twice as high as that of males of similar age in the United States.

In 1911 the general death-rate of Chicago was 14.5 and that of Cambridge, Mass., was 15.2. Was Chicago the healthier city? No, indeed! The following figures show that the specific death-rates were lower in Cambridge for all ages except the age-intervals of 10–19 years and 65 years and over. The reason for Chicago's lower rate was because there were relatively more people in Chicago at those middle ages where the specific death-rates are naturally low.

TABLE 66

COMPARISON OF DEATH-RATES IN CAMBRIDGE, MASS., AND CHICAGO

Age in years	Per cent of population in age-groups Both sexes. 1910		Specific death-rates per 1000, in 1911	
	Cambridge	Chicago	Cambridge	Chicago.
(1)	(2)	(3)	(4)	(5)
Under 5	10 3	10 2	39 1	39.5
5–9	9 1	8 8	4 3	4 7
10–14	8.5	8 6	3 5	2 6
15–19	8 5	9 6	4 6	3 7
20–24	9 9	11 5	3 8	5.3
25–34	18 2	19 7	5 5	6 9
35–44	15 0	14 5	9 0	11 4
45–54	16 0	9 6	16 0	19 3
55–64	.	4 5	29 4	35 1
65–74	4 5	2 0	64 0	63.6
75 and over (including unknown)		1 0	148 8	144 2
Total	100 0	100 0	15.2	14.5

Obviously the two general death-rates tell us very little that we want to know — that is, not until they have been analyzed.

Effect of race composition on death-rates. — If different races have different specific death-rates then the general death-rates of two places which have different percentages of various races cannot be fairly compared. The general death-rates of southern cities cannot be fairly compared with those of northern cities. In 1911 the general death-rate in New York City was 15.2; in Washington it was 18.7; in New Orleans, 20.4. The death-rate for the white population in Washington, however, was only 15.5 and in New Orleans only 16.6. Even these figures are not strictly comparable as they do not take into account age distribution.

Changes in specific death-rates through long periods. — We have seen that the general, or gross, death-rates have been falling for a long time. Are the same changes occurring in the specific death-rates at different ages and for different classes of the population? This is a most important question. If we can answer it we shall have come close to measuring the effect of our sanitary, hygienic and medical improvements during recent years. Far too little effort has been made to compile statistics of this sort. Let us see what we can learn from Massachusetts records.

In 1830 Lemuel Shattuck computed specific death-rates for Boston. It will be interesting to compare these with figures for the year 1911, published in the U. S. Mortality Statistics by the Bureau of the Census and recast to make the age-groups correspond.

TABLE 67

SPECIFIC DEATH-RATES, BOTH SEXES, FOR BOSTON

Age interval	Rate per 1000	
	1830	1911
(1)	(2)	(3)
		(approximate)
0–1	.	161
1–5	.	17
0–5	59 6	. . .
5–9	8 1	4
10–14	5 5	2 4
15–19	4 9	4
20–29	10 4	6
30–39	20 1	10
40–49	22 4	15
50–59	29 3	27
60–69	45 8	52
70–79	92 4	102
80–89	162 1	. .
90–	321 4	. . . .

During the 81 years there has been a marked reduction in the specific death-rates at all ages below sixty. In the case of children and youths the reduction was as much as one half. In 1898 Dr. Samuel W. Abbott, then Secretary of the Massachusetts State Board of Health, computed a life table for the State[1] for the years 1893–7 in which the specific death-rates were given for certain age-groups. It is interesting to compare these with the figures given for Massachusetts in the U. S. Life Tables for 1910.

[1] Ann. Rept. 1898, p. 810.

TABLE 68

SPECIFIC DEATH-RATES FOR MASSACHUSETTS

Age-group.	Rate per 1000 1893–7		Age-group.	Rate per 1000 1910	
	Males	Females		Males	Females.
(1)	(2)	(3)	(4)	(5)	(6)
0–4	60 12	52 22			
5–9	5 69	5 82	7–8	3 37	3 13
10–14	3.11	3 40	12–13	2 27	2 05
15–19	5 29	5 68	17–18	3 43	3 17
20–24	7 48	7 32	22–23	5 16	4 30
25–34	9.33	8 78	30–31	6 60	5 97
35–44	11 19	10 74	40–41	10 00	8 14
45–54	16 67	14 88	50–51	16 05	12.58
55–64	30 42	26 00	60–61	33 15	27 03
65–74	59 67	51 37	70–71	67.91	56 47
75–84	116 20	99 88	80–81	137 43	123 49
85–94	223 50	184 81	90–91	251 53	244 90
95–	429 20	367 07	100–101	483 90	392 91

Here we see the specific death-rates still falling up to age sixty. For the later ages there has been a slight tendency to increase. It should be noticed, however, that the age-groups are not quite the same for the two periods.

In 1830 and also in 1893–7 the specific rates at ages five to twenty, or thereabouts, were higher for females than for males, but in 1910 the opposite was true.

If we should make similar comparisons of specific death-rates for other places and for different periods we should almost always find that in recent years the rates have been falling for all ages below fifty or sixty.

What have been the reasons for this reduction? Undoubtedly improved sanitary and hygienic conditions, advances in medical and surgical science and the arts of preventive medicine have tended to reduce the number of

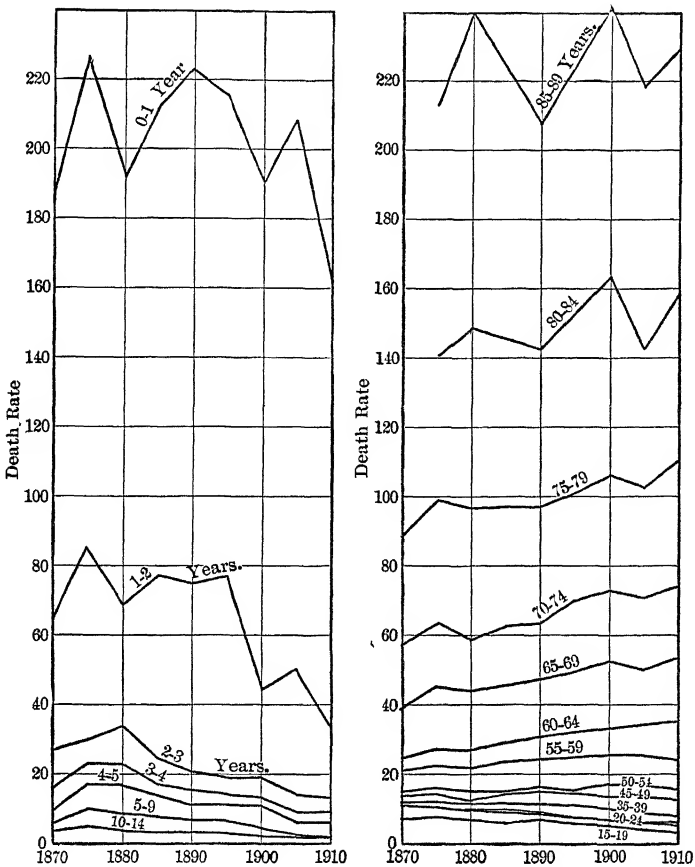


FIG. 68. — Specific Death-rates by Age-Groups, Massachusetts, 1870–1910.

cases of sickness and to increase the percentage of recoveries of those who are taken sick. This has been especially true in the earlier ages. But it must not be forgotten that changes in the relative numbers of married and single persons in each sex, and of persons of different nationality, have also their influence. A reason for the increase in the specific death-rates above fifty or sixty years of age has been frequently discussed of late, namely an increase in certain degenerative and organic diseases. This is important, if true, but it is a difficult thing to prove.

The fallacy of concealed classification. — Now that we have come to appreciate the effect of age, sex, nationality, and such factors on death-rates, but especially the factor of age, we can better understand what may be called the fallacy of concealed classification. If we classify males according to occupation we might find that the death-rate of bank presidents was higher than that of newsboys; but this would not be because of different occupation but because of different ages. In classifying by occupation we have concealed a grouping by age. If, in classifying the employees of the city of Boston or New York by occupation we distinguish between policemen and street cleaners, we might find that we had concealed a classification by nationality, the street cleaners being Italians and the policemen Irishmen. Similarly in classifying railroad employees into conductors and brakemen, we might conceal age differences, and under the class of Pullman porters we might conceal a nationality difference. When we consider stenographers as a separate class we conceal a classification by sex. These concealed classifications and groupings are sometimes very illusive; they creep into our statistics unawares and upset what might otherwise be sound reasoning. Illustrations may be found on every hand. Every one who uses statistics should be continually on the watch for them.

Use of specific death-rates. — It must be evident from what has been said that in order to compare the mortality conditions in various places the best way is to compare age with age, sex with sex, nationality with nationality, or in other words to compare the various places, classes and groups on the basis of their specific death-rates. To do this in great detail involves labor and the use of many figures. Hence there has always been a fascination in combining these figures so as to obtain a single figure which may be regarded as an index of mortality. There are at least two ways of doing this. If there were such a thing as a standard population — and several such standards have been suggested, notably the Standard Million (see page 192) — and if we knew the specific death-rates by ages and sex for any place, we could apply these rates to the standard population and find what the general death-rate would have been in the given place if the population had been standard. And we might do the same for another place and thus obtain figures for the death-rates which could be compared with some degree of justice.

When general death-rates are adjusted to a standard population in this way the results are called "*Standardized death-rates.*" Sometimes they have been referred to as "corrected" death-rates, but this is a poor use of the word, for the process is not one of correcting errors or mistakes and the final result is not "correct," for it does not take into account all differences in population. Nor is the expression "standardized" a good one, because it is not the death-rate which is standardized, but only the population. A better term is "Death-rates adjusted to a Standard Population."

In the annual report of the Massachusetts State Board of Health for 1902 may be found another method of "correcting" death-rates, used by Dr. Samuel W. Abbott. He took as a standard the specific death-rates of Massachusetts by age and sex. He then applied these to the age and sex groups of the cities of the state, to obtain what he called the standard death-rate for each place. Then he found the ratio between the "standard death-rate" for each place and the general death-rate of the state, and called this the "factor of correction." Finally he multiplied the actual general death-rate of each place by this factor to obtain his "corrected death-rate." The advantage of this method was that he did not need to use the age distribution of deaths for each place. The method is interesting, but is not one for general adoption, because it would be hard to decide on a standard of specific death-rates.

Another way of using specific death-rates is that of constructing what are called life tables. These will be described in Chapter XV.

But the best way of using specific death-rates is to use them directly. To be sure it means that one must carry more figures in one's mind. Instead of having to think of one figure for the general death-rate it is necessary to think of figures for infant deaths, for the deaths of children, of adults and of the aged — but, after all, are not these the really important figures? Statistics are worthless unless they can be used. If specific death-rates are more usable than general death-rates, we should make the specific rates more prominent and educate people to think in terms of them.

Death-rates adjusted to a standard population. — A few examples will now be given to show how general rates may be adjusted to a standard population. For the sake of simplicity age differences only will be considered. The data required are (*a*) the number of deaths by age-groups in the given place; (*b*) the number of persons living at mid-year in the corresponding age-groups; (*c*) an assumed standard population for the same age-grouping. First of all, therefore, some system of age-grouping must be decided upon. Let us take first a simple case, that is, one where there are only a few groups.

On page 278 were given data for New South Wales, from which the specific death-rates were computed. Let us apply these specific death-rates to the population of Sweden in 1890 which we will take as a standard. This is given in column (5) of Table 69. For age-group 1–19 years the specific rate was 2.78 per 1000; hence, among 398 persons the number of deaths would be 0.398 × 2.78 or 1.11 as given in column (6). And so for the other age-groups. The figures in column (6), therefore, give the number of deaths in each group of the standard thousand of population, and their sum is the total number of deaths in the standard thousand. Hence the death-rate of New South Wales adjusted to the standard population was 13.44. This is much higher than the general death-rate, which was only 9.85.

TABLE 69

ADJUSTED DEATH-RATE FOR NEW SOUTH WALES, 1901

Age-group in years	Population.	Number of deaths in one year.	Specific death-rate per 1000.	Standard age distribution per 1000.	Computed deaths per 1000 of total population.
(1)	(2)	(3)	(4)	(5)	(6)
0–1	40,500	3,234	79 88	25 5	2 04
1–19	704,000	1,960	2 78	398 0	1 11
20–39	514,900	2,251	4 37	269 6	1 18
40–59	256,600	2,965	11 56	192 3	2 22
60 and over	89,800	5,400	60 13	114 6	6 89
Total	1,605,800	15,810	9 85	1000 0	13.44

Why this difference? The answer is found by comparing the age distribution of the people of New South Wales with the assumed standard population.

TABLE 70

COMPARISON OF POPULATION DISTRIBUTION OF NEW SOUTH WALES WITH THAT OF SWEDEN IN 1890

Age-group	New South Wales Number.	New South Wales Per thousand.	Sweden. Per thousand.
(1)	(2)	(3)	(4)
0–1	40,500	24 9	25 5
1–19	704,000	439 0	398 0
30–39	514,900	320.0	269 6
40–59	256,600	160 5	192 3
60–	89,800	55 6	114 6
All Ages	1,605,800	1000 0	1000 0

It will be seen that in New South Wales there were fewer old persons, for whom the specific death-rates are naturally high, but more persons in middle life, for whom the specific death-rates are naturally low. This is an extreme case, but characteristic of a new population built up by immigration.

Let us now take a more complicated situation.

In 1914 there were 1452 deaths in Cambridge,[1] Mass., distributed by age as follows:

TABLE 71

DISTRIBUTION OF DEATHS: CAMBRIDGE, MASS., 1914

Age	Number	Age.	Number.	Age.	Number.	Age	Number.
(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
[0–1]	[243]	20–24	43	45–49	90	70–74	110
0–5	340	25–29	49	50–54	83	75–79	72
5–9	20	30–34	62	55–59	73	80–84	66
10–14	26	35–39	58	60–64	107	85–89	33
15–19	33	40–44	56	65–69	109	90–94	18
						95–99	4

[1] U. S. Mortality Statistics, 1914, p. 264.

The Standard Million[1] will be taken as the standard of population. It is necessary to take an age-grouping which will correspond to this, and find the number of persons in Cambridge in 1914 in each of these groups. There was no census in Cambridge in 1914, but in 1910 the population was 104,839, in 1900 it was 91,886. The estimated population July 1, 1914, was 110,357. In 1910 the age distribution of the people of Cambridge was given by the census. It was as follows (columns 1, 2 and 3):

TABLE 72

PERSONS LESS THAN STATED AGE: CAMBRIDGE, MASS.

Age	Actual number of persons in 1910	Per cent	Computed number of persons in 1914.
(1)	(2)	(3)	(4)
1	2,323	2 3	2,430
5	10,802	10 4	11,500
10	20,273	19 4	21,400
15	29,165	27 9	30,800
20	37,095	36 4	40,200
25	47,503	46 4	51,200
35	66,678	64 6	70,500
45	82,404	79 6	88,000
65	99,136	95 6	105,700
100	104,778	99 4	110,280
Unknown	61	0 6	77
Total	104,839	100 0	110,357

It may be fairly assumed that the percentages of column 3 for 1910 apply also with no great change to 1914. By multiplying 110,357, therefore, by these percentages we get the following numbers of persons in each group for 1914 (column 4).

The figures in column (4) may be redistributed in any

[1] See p. 192.

desired age-grouping as described on p. 183. In this way the figures in column (2) of the following table were obtained:

TABLE 73

ADJUSTED DEATH-RATES FOR CAMBRIDGE, MASS.

Age-group	Estimated population in 1914 (approximate)	Number of deaths in 1914.	Specific death-rate per 1000.	Standard age distribution per 1000.	Computed deaths.
(1)	(2)	(3)	(4)	(5)	(6)
0–4	11,500	340	29 5	114 262	3 380
5–9	9,900	20	2 02	107 209	0 217
10–14	9,400	26	2 76	102 735	0 284
15–19	9,400	33	3 51	99 796	0 350
20–24	11,000	43	3 91	95 946	0 374
25–34	19,200	111	5 78	161 579	0 935
35–44	17,400	114	6 53	122 849	0 803
45–54	11,600	173	14 9	89 222	1 330
55–64	5,800	180	31 1	59 741	1 856
65–74	3,100	219	70 6	33.080	2 330
75–	2,100	193	91.8	13.581	1 246
Total	110,400	1452	13 15	1000 000	13.105

From columns (2) and (3) the specific death-rates are obtained (column 4), and these applied to the standard age distribution (column 5) give the number of computed deaths in each age-group (column 6). Their sum gives 13.1, which is the death-rate adjusted to the standard age distribution. We have done all this work to get a result which differs but fractionally from the general, or crude death-rate, *i.e.*, 13.15. Not worth while? Yes, it is if we are to use a death-rate at all. It was only because the age distribution of the Cambridge population happened to be so near that of the standard million that the two death-rates came so close together. In another case the result might be very different.

A fair criticism of this last computation would be that the age-groupings below age five and above middle age are too wide, for it is in these groups where the specific death-rates are highest. Dr. Wm. L. Holt, C.P.H. (School of Public Health, Harvard University and Mass. Inst. of Tech.), investigated this subject of grouping and concluded that seven properly selected groups would give results which compared well with those obtained by using the eleven groups of the Standard Million. The author believes that even five well-chosen groups would suffice, but the matter is one which needs free discussion. Certainly something more convenient than the Standard Million is possible.

TABLE 74

COMPUTED DEATH-RATES IN BOSTON AND CAMBRIDGE, 1905

(Computations by Dr. Wm. L. Holt)

Boston.

Age-group.	Population.	Deaths.	Specific death-rate.	Adjusted rates per 1000			
				Eleven groups	Nine groups.	Seven groups	Six groups.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
0–4	52,152	3128	60 1	6 850	6 850	6 850	6 850
5–9	54,091	253	4 68	0 501	0 501		
10–14	48,694	157	3 22	0 331	0 785	1 963	1 963
15–19	47,608	218	4 58	0 457			
20–24	57,421	380	6 61	0 634	0 634		
25–34	119,632	1070	8 95	1.441	1 441	2 840	2.840
35–44	95,946	1081	11 28	1 388	1 388		
45–54	58,810	1255	21.4	1 910	1 910	1 910	4 135
55–64	33,602	1308	38 9	2 325	2 325	2 325	
65–74	16,711	1213	72 6	2.403	4 802	2 403	2 403
75–	6,413	937	146 0	1 980		1 980	1 980
Total				20 220	20 636	20 271	20.171

(Continued on next page.)

Cambridge

Age-group.	Population	Deaths.	Specific death-rate	Adjusted rates per 1000	
				Eleven groups.	Seven groups.
(1)	(2)	(3)	(4)	(5)	(6)
0–4	9,088	412	45 3	5 176	5 176
5–9	9,096	27	2 96	0 317	
10-14	8,078	20	2 48	0 255	1 468
15–19	8,512	34	4 00	0 399	
20–24	10,789	51	4 72	0 452	
25–34	18,671	130	6 97	1 125	2 253
35–44	14,148	130	9.19	1 127	
45–54	9,267	133	14 35	1 280	1 280
55–64	5,628	165	29 4	1 755	1 755
65–74	2,864	155	54 1	1 790	1 790
75–	1,251	179	143 2	1 950	1 950
Total				15 626	15 672

Examples of death-rates adjusted to a standard population. — The U. S. Mortality Statistics give numerous examples of death-rates adjusted to the Standard Million.

Let us first of all compare Cambridge, Mass., and Chicago, Ill.

TABLE **75**

City.	Death-rate, 1911.	
	Gross.	Adjusted.
(1)	(2)	(3)
Cambridge, Mass.	15 2	15 4
Chicago, Ill.	14 5	16 4

Here again we see that adjustment of the Cambridge rate changes it but little,[1] while that of Chicago was increased by 1.9, making the adjusted rate higher than that of Cambridge. Why?

[1] In this computation sex as well as age was considered.

In every instance in the following table the adjusted death-rate exceeded the gross death-rate, the excesses ranging from 1 to 18 per cent and averaging 8.4 per cent. As would naturally be expected the differences were less in the older cities of the East than in the newer cities of the West, but New York, Pittsburgh and a few others with large numbers of recent immigrants were exceptions to this rule. The following figures illustrate this:

TABLE 76

COMPARISON OF GROSS AND ADJUSTED DEATH-RATES FOR CERTAIN CITIES

City.	Death-rates per 1000		
	Gross.	Adjusted.	Difference.
(1)	(2)	(3)	(4)
New Haven, Conn.	16 7	17 7	1 0
Boston, Mass.	17 1	17 9	0 8
New York, N. Y.	15 2	17.2	2 0
Pittsburgh, Pa.	14 9	16 9	2 0
Cleveland, Ohio	13 8	15.3	1.5
Chicago, Ill.	14.5	16 4	1 9
Spokane, Wash.	11.6	13 7	2.1
Seattle, Wash.	8 8	10 4	1.6

Adjustment to a standard population tends to equalize the death-rates in different places. The rural districts of New England contain a large percentage of persons of advanced age. This tends to cause the adjusted rate to be lower than the gross rate. Taking figures for entire states we find this to be true, as the following figures show. In the western states this difference is not as marked, as they have not suffered by emigration as have the New England States.

TABLE 77

COMPARISON OF GROSS AND ADJUSTED DEATH-RATES FOR CERTAIN STATES

State.	Death-rates per 1000.		
	Gross	Adjusted	Difference.
(1)	(2)	(3)	(4)
Massachusetts	15 3	15 0	−0 3
New Hampshire	17 1	14 2	−2 9
Maine	16 1	13 0	−3.1
Connecticut	15 4	14 8	−0 6
Indiana	12 9	12 3	−0 6
Kentucky	13 2	13 4	0 2
Michigan	13 2	12 4	−0 8
Minnesota	10 5	10 8	0 3
Missouri	13 1	13 1	0 0
Montana	10 2	11.6	1.4

The following figures show the relation between the crude and adjusted death-rates for various countries:

TABLE 78

COMPARISON OF GROSS AND ADJUSTED DEATH-RATES FOR CERTAIN COUNTRIES

Country.	Year.	Death-rates per 1000.			Ratio of adjusted rate to that of England and Wales.
		Gross.	Adjusted	Difference	
(1)	(2)	(3)	(4)	(5)	(6)
Russia	1896-1898	32 80	28 61	−4 19	166 7
Spain	1900-1902	27 63	26 53	−1 10	154 6
Austria	1899-1901	24 83	23 12	−1 71	134 7
Italy	1900-1902	22 72	20 23	−2 49	117 9
Germany	1901	20 84	19 52	−1 32	113 8
U. S. (Registration area)	1900	17 55	18 05	0 50	105 2
Scotland	1900-1902	17 91	17 61	−0 30	102 6
France	1900-1902	20 80	17 50	−3 30	102 0
England & Wales	1900-1902	17 16	17 16	0 00	100 0
Switzerland	1899-1901	18 22	16 86	−1 36	98 3
Belgium	1899-1901	18 53	16 78	−1 75	97 8
Ireland	1900-1902	18 27	16.59	−1 68	96 7
Netherlands	1898-1900	17.32	15 40	−1.92	89 7
Sweden	1899-1901	16 78	13 88	−2 90	80 9
New South Wales	1900-1902	11 72	13 10	1 38	76 3
Victoria	1900-1902	13 12	13 08	−0.04	76 2
South Australia	1900-1902	11 02	11 73	0 71	68 4

Adjustment for racial differences. — In certain parts of the United States, especially in the South, the crude death-rates are absolutely useless for purposes of comparison unless allowance is made for the number of colored persons at different ages. The specific death-rates for colored persons are higher at all ages than for white persons, as the following figures for the U. S. registration states in 1900 show:

TABLE **79**

COMPARISON OF SPECIFIC DEATH-RATES FOR WHITE AND COLORED PERSONS

Age-group (both sexes).	Death-rates per 1000 (exclusive of still-births).		Ratio of colored to white death-rate.
	Native white.	Colored.	
(1)	(2)	(3)	(4)
0–4	49 1	106 4	2.17
5–9	4 5	8 9	1 98
10–14	2 9	9 0	3.10
15–19	4 7	11.4	2 43
20–24	6 8	11.6	1 71
25–34	8 2	12 2	1 49
35–44	9 6	15 0	1 56
45–54	12.7	24 5	1.93
55–64	22 6	42 5	1 88
65–74	50 4	69.5	1.38
75	138.5	143 3	1 03
Crude death-rate	16.5	25.0	1.52

The following figures for the cities of Washington, Baltimore and New Orleans show the necessity of taking into account these striking differences between the white and colored people:

TABLE 80

ADJUSTED DEATH-RATES FOR CITIES HAVING LARGE COLORED POPULATIONS

	Death-rates per 1000 (both sexes), 1911.		
	Gross.	Adjusted.	Difference.
(1)	(2)	(3)	(4)
Washington, D. C.			
White	15 5	14 6	−0.9
Colored	26 6	30 5	3 9
Total	18 7	18 9	0 2
Baltimore, Md.			
White	16 2	16 7	0 5
Colored	30 9	35 4	4 5
Total	18 4	19 4	1 0
New Orleans, La.			
White	16 6	17 5	0 9
Colored	31.2	34 0	2.8
Total	20 4	21 8	1.4

Death-rates for particular diseases. — Death-rates for particular diseases are computed in the same way as other specific death-rates. The numerator of the ratio is limited to the disease in question. The denominator may be the entire population, or it may be confined to some specific part of it. In order to avoid the use of too many decimals it is well to express the death-rates for particular diseases as so many per 100,000 instead of so many per 1000. This practice is becoming universal. The use of 10,000 as a base should be avoided.

If all of the deaths from typhoid fever be compared with the total mid-year population, we have the general typhoid fever death-rate of the place. General rates for particular diseases are much used and have practical value. Specific rates in which deaths from typhoid fever in a given age-group are compared with the population in the same age-group are sometimes computed, but are useful only when the numbers involved are large.

Special death-rates. — In epidemiological studies it is necessary to compute death-rates in all sorts of ways, to separate the people into classes according to where and how they live, according to their occupation or their exposure to certain risks. This causes us to deal with many special rates.

In studying birth statistics we may find the general birth-rate, by taking the ratio between the number of births and the total population. But we may also desire to find the ratio between births and women of child-bearing age, or between births and married women of child-bearing age.

In interpreting all of these many sorts of rates and ratios the principles already outlined hold good. We must see that the data compared are logically comparable, that there are no concealed classifications and that the rules of precision are not violated.

EXERCISES AND QUESTIONS

1. Are the changes in age-composition from decade to decade in Massachusetts sufficient to explain a considerable part of the falling general death-rate of the state, assuming the specific death-rates by ages to remain constant?

2. Compute the specific death-rates by sex and age-groups for three Massachusetts cities for 1910, obtaining data from the census and registration reports.

3. Compare the specific death-rates by age-groups for white and colored persons in some southern city for some selected year.

4. Adjust the death-rate of some western city in 1910 to the Swedish standard of population.

5. Repeat this computation using the standard million as a basis of adjustment.

6. Select from the Mortality Reports examples of the need of adjustment of death-rates of cities for purposes of comparison.

7. Adjust the death-rates of some selected city to the basis of the Standard Million for 1915, 1910, 1905, 1900 and as far back as record can be obtained.

CHAPTER IX

CAUSES OF DEATH

Nosography. — The description and systematic classification of disease is called nosography. The word is derived from the Greek word *nosos*, which means sickness, or disease. (The word is pronounced noss-ography, not noze-ography.)

Nosology. — The science of classifying disease is similarly called nosology.

The purpose of nosology. — At one time it was thought that a knowledge of nosology was necessary for the practical treatment of disease. Many systems were proposed and abandoned. Today the idea has few, if any, supporters.

Nosology is of great importance as one of the foundation stones of our modern structure of vital statistics. Without uniform definitions of disease, which furnish us with adequate statistical units, our statistics would be worthless. It is because of changes in the definitions of disease that we fall into so many errors in comparing past conditions with those of the present day. Such changes are inevitable as medical science advances, but they ought to be universally recognized when they are made.

Dr. William Farr was one of the first to recognize the importance of "statistical nosology."

History of nosography. — Nosography emerged from its former chaotic condition in 1893 when the use of the International Classification of Diseases and Causes of Death was begun. This was due chiefly to the labors of Dr. Jacques Bertillon of France.

In 1853 Dr. William Farr and Dr. Marc d'Espine, of Geneva, had been selected by the First Statistical Congress, which met at Brussels, to present a report on the subject. The list of diseases reported by them was adopted in Paris in 1855, in Vienna in 1857, and was translated into six languages. It was revised several times between 1864 and 1886. In 1893 the International Statistical Institute, the successor of the Statistical Congress, met in Chicago and adopted this list with some changes. Provision was made for decennial revisions by an International Commission, and such revisions were made in Paris in 1900 and again in 1909, the latter a year earlier in order that the new list might be used in the censuses of 1910. This list was intended to stand unchanged until 1919. In 1898 the International List was endorsed by the American Public Health Association. England adopted the list in 1911. It was used by all English and Spanish speaking countries, but it did not become universal. A few of our own states did not follow it exactly.

On account of the war no revision of the list was made in 1919; but, largely through the efforts of the League of Red Cross Societies, a convention representing national governments met in Paris, October 11–14, 1920. This was known as the Third International Commission for the Revision of the Classification of the Causes of Death (Nosologic nomenclature).

Classification of diseases in 1850. — Dr. Farr classified diseases as follows:

CLASS I. EPIDEMIC, ENDEMIC AND CONTAGIOUS DISEASES (*Zymotici*).
- Order 1. *Miasmatic* diseases, — small-pox, ague, etc.
- Order 2. *Enthenic* diseases, — syphilis, glanders.
- Order 3. *Dietetic* diseases, — scurvy, ergotism.
- Order 4. *Parasitic* diseases.

CLASS II. CONSTITUTIONAL DISEASES (*Cachectici*).
- Order 1. *Diathetic* diseases, — gout, dropsy, cancer, etc.
- Order 2. *Tubercular* diseases, — scrofula, consumption.

CLASS III. LOCAL DISEASES (*Monorganici*).
- Order 1. Diseases of the brain.
- Order 2. Diseases of the circulation.

Order 3. Diseases of respiration.
Order 4. Diseases of digestion.
Order 5. Diseases of the urinary system.
Order 6. Diseases of reproduction.
Order 7. Diseases of locomotive system.
Order 8 Diseases of integumentary system.

CLASS IV. DEVELOPMENTAL DISEASES (*Metamorphici*).

CLASS V. VIOLENT DEATHS OR DISEASES (*Thanatici*).

It is extremely interesting to study this list in detail as given in the 16th Annual Report of the Registrar General of England, Appendix, pp. 71–79.

International List of 1920. — The International List of 1909 recognized 189 causes of death, which were divided into fourteen classes. It was not claimed that these were all of the possible causes. For convenience of reference each cause of death was given a number. The International List of 1920 has 206 titles. In consequence of this increase, and because of the shifting of certain diseases from one class to another many diseases now bear different numbers from those with which health officers and registrars became familiar during the period from 1909 to 1920. It is to be regretted that the Congress of 1920 did not adopt a system of permanent numbering, perhaps similar to the Dewey decimal system used in libraries, which would leave unchanged the numbers of the well recognized diseases and be elastic enough to provide for inevitable changes and additions. This will doubtless come in time. Until then students must be on their guard when making comparisons for different years.

The following comparison shows some of the differences between the list of 1909 and that of 1920.

1909	1920
I. General Causes. Nos. 1 to 59.	I. Endemic, Epidemic and Infectious Diseases. Nos 1 to 42.
II. Diseases of the Nervous System and the Organs of Special Sense. Nos. 60 to 76.	II. General Diseases not included above. Nos. 43 to 69.

1909

III. Diseases of the Circulatory System. Nos. 77 to 85.
IV. Diseases of the Respiratory System. Nos 86 to 98.
V. Diseases of the Digestive System. Nos 99 to 118.
VI. Non-venereal Diseases of the Genito-urinary System and Annexa. Nos. 119 to 133.
VII. The Puerperal State. Nos. 134 to 145.
VIII. Diseases of the Skin and Cellular Tissue. Nos. 142 to 145.
IX. Diseases of the Bones and of the Organs of Locomotion. Nos. 146 to 149.
X. Malformations. No. 150.
XI. Diseases of Early Infancy. Nos. 151 to 153.
XII. Old Age. No. 154.
XIII. Affections produced by External Causes. Nos. 155 to 186.
XIV. Ill-defined Diseases. Nos. 187 to 189.

1920

III. Diseases of the Nervous System and Sense Organs. Nos. 70 to 86.
IV. Diseases of the Circulatory System. Nos. 87 to 96.
V. Diseases of the Respiratory System. Nos. 97 to 107.
VI. Diseases of the Digestive System. Nos. 108 to 127.
VII. Non-venereal Diseases of the Genito-Urinary System and Annexa. Nos. 128 to 142.
VIII. The Puerperal State. Nos. 143 to 150.
IX. Diseases of the Skin and Cellular Tissue. Nos. 151 to 155.
X. Diseases of the Bones and Organs of Locomotion. Nos. 156 to 158.
XI. Malformations. No. 159.
XII. Diseases of Early Infancy. Nos. 160 to 163.
XIII. Old Age. No. 164
XIV. External Causes. Nos. 165 to 203.
XV. Ill-defined Diseases. Nos. 204 to 205.
XVI. Diseases omitted as having caused less than 10 deaths. No. 206.

INTERNATIONAL LIST OF CAUSES OF SICKNESS AND DEATH

(Third decennial revision by the International Commission, Paris, Oct. 11-14, 1920.)

(The titles preceded by a star indicate certain additional subdivisions which the U.S. Census Bureau intends to use to facilitate comparisons with statistics of previous years. The numbers in parentheses after the titles are those of the 1909 list and are given for comparison. They should not now be used)

I. — Epidemic, Endemic and Infectious Diseases

1. **Typhoid and paratyphoid fever** (1).
   (*a*) Typhoid fever.
   (*b*) Paratyphoid fever.
2. **Typhus fever** (2).
3. **Relapsing fever (spirillum obermeieri) (3).**

4. Malta fever or Mediterranean fever. ("Melito-coccosis")
5. Malaria (4).
   (*a*) Malarial fever.
   (*b*) Malarial cachexia.
6. Small-pox (5).
7. Measles (6).
8. Scarlet fever (7).
9. Whooping cough (8).
10. Diphtheria (9).
11. Influenza (10)
    (*a*) with pulmonary complications specified
    (*b*) without pulmonary complications specified.
12. Miliary fever (11).
13. *Mumps* (19).
14. Asiatic cholera (12).
15. Cholera nostras (choleriform enteritis) (13).
16. Dysentery (14).
    (*a*) amebic.
    (*b*) bacillary.
    (*c*) due to other causes.
17. Plague (15).
    (*a*) bubonic.
    (*b*) pneumonic.
    (*c*) septicemic.
    (*d*) unspecified.
18. Yellow fever (16).
19. Spirochetal hemorrhagic jaundice (Spirochaetosis ictero-haemorrhagica).
20. Leprosy (17).
21. Erysipelas (18).
22. Acute poliomyelitis.
23. Encephalitis-lethargica.
24. Meningococcal meningitis.
25. Other epidemic and endemic diseases (19).
    *(*a*) Chicken-pox.
    *(*b*) German measles.
    *(*c*) Others under this title.
26. Glanders (21).
27. Anthrax (22).
28. Rabies (23).
29. Tetanus (24).
30. Mycoses (25).
31. Tuberculosis of the respiratory system (28).
32. Tuberculosis of the meninges and central nervous system generally (30).
33. Tuberculosis of the intestines and peritoneum (31).
34. Tuberculosis of the vertebral column (32).
35. Tuberculosis of the joints (33).
36. Tuberculosis of other organs (34).
    (*a*) Tuberculosis of the skin and subcutaneous cellular tissue.
    (*b*) Tuberculosis of the bones (vertebral column excepted).

(*c*) Tuberculosis of the lymphatic system (mesenteric and retroperitoneal glands excepted).
(*d*) Tuberculosis of the genito-urinary system.
(*e*) Tuberculosis of organs other than the above.

37. **Disseminated tuberculosis.**
(*a*) acute (29).
(*b*) chronic.
38. **Syphilis** (37).
(*a*) *Primary.*
(*b*) *Secondary.*
(*c*) *Tertiary.*
(*d*) *Hereditary.*
(*e*) *Stage not indicated.*
39. **Soft chancre** (37).
40A. **Gonococcal infection** (ophthalmia excepted).
40B *Gonorrhœal or purulent ophthalmia infection* (38).
41. **Purulent infection, septicemia** (38).
42. Other infectious diseases.

II. — General Diseases not Included Above

43. **Cancer and other malignant tumors of the buccal cavity** (39).
44. **Cancer and other malignant tumors of the stomach and liver** (40).
45. **Cancer and other malignant tumors of the peritoneum, intestines and rectum** (41).
46. **Cancer and other malignant tumors of the female genital organs** (42).
47. **Cancer and other malignant tumors of the breast** (43).
48. **Cancer and other malignant tumors of the skin** (44).
49. **Cancer and other malignant tumors of other or unspecified organs** (45).
50. **Benign tumors and tumors not returned as malignant** (tumors of the female genital organs excepted) (46).
51. **Acute rheumatic fever** (47).
52. **Chronic rheumatism, osteo-arthritis, gout** (48).
53. **Scurvy** (49).
54. **Pellagra** (26).
55. **Beriberi** (27).
56. **Rickets** (36).
57. **Diabetes mellitus** (50).
58. **Anemia, chlorosis** (54).
(*a*) Pernicious anemia.
(*b*) Other anemias and chlorosis.
59. **Diseases of the pituitary gland.**
60. **Diseases of the thyroid gland.**
(*a*) Exophthalmic goiter (51).
(*b*) Other diseases of the thyroid gland (88)
61. **Diseases of the parathyroid glands** (88).
62. **Diseases of the thymus gland** (88).
63. **Diseases of the adrenals (Addison's disease)** (52).
64. **Diseases of the spleen.**
65. **Leukemia and Lymphadenoma (Hodgkin's disease)** (53).
(*a*) Leukemia.
(*b*) Lymphadenoma.

66. **Alcoholism (acute or chronic)** (56).
67. **Chronic poisoning by mineral substances.**
    *(*a*) Chronic lead poisoning (57).
    *(*b*) Others under this title (58).
68. **Chronic poisoning by organic substances** (58).
69. Other general diseases (55).

III. — Diseases of the Nervous System and of the Organs of Special Sense

70. **Encephalitis** (60).
71. **Meningitis** (does not include meningitis specified as meningococcic, tuberculous, rheumatic, etc) (61).
    *(*a*) Simple meningitis
    *(*b*) Non-epidemic cerebrospinal meningitis.
72 **Tabes dorsalis (locomotor ataxia)** (62).
73. **Other diseases of the spinal cord** (63).
74. **Cerebral hemorrhage, apoplexy** (64).
    (*a*) Cerebral hemorrhage
    (*b*) Cerebral thrombosis and embolism.
75. **Paralysis without specified cause** (66).
    (*a*) Hemiplegia.
    (*b*) Others under this title.
76. **General paralysis of the insane** (67).
77. **Other forms of mental alienation** (68).
78. **Epilepsy** (69).
79. **Convulsions (non-puerperal)** (5 years and over) (70).
80. **Infantile convulsions** (under 5 years of age) (71).
81. **Chorea** (72).
82A. *Hysteria and neuralgia* (73).
82B. **Neuritis** (73).
83. **Cerebral softening** (65).
84. **Other diseases of the nervous system** (74).
85. **Diseases of the eye and annexa** (75).
    (*a*) *Diseases of the organs of the eye.*
    (*b*) *Follicular conjunctivitis.*
    (*c*) *Trachoma.*
    (*d*) *Tumors of the eye.*
    (*e*) *Other diseases of the eye and annexa.*
86. **Diseases of the ear and of the mastoid sinus** (76).
    *(*a*) Diseases of the ear.
    *(*b*) Diseases of the mastoid process.

IV. — Diseases of the Circulatory System

87. **Pericarditis** (77).
88. **Endocarditis and myocarditis (acute)** (78).
89. **Angina pectoris** (80).
90. **Other diseases of the heart** (79).
91. **Diseases of the arteries** (81).
    (*a*) Aneurism.
    (*b*) *Arteriosclerosis*
    (*c*) Other diseases of the arteries.
92. **Embolism and thrombosis (not cerebral)** (82).
93. **Diseases of the veins (varices, hemorrhoids, phlebitis, etc.)** (83).

94. **Diseases of the lymphatic system (lymphangitis, etc.)** (84).
95. **Hemorrhage without specified cause** (85)
96. **Other diseases of the circulatory system** (85).

V. — Diseases of the Respiratory System

97. **Diseases of the nasal fossae and their annexa** (86).
    *(*a*) Diseases of the nasal fossae.
    *(*b*) Others under this title.
98. **Diseases of the larynx** (87).
99. **Bronchitis.**
    (*a*) acute (89).
    (*b*) chronic (90).
    (*c*) not otherwise defined under 5 years of age.
    (*d*) not otherwise defined 5 years and over
100. **Bronchopneumonia (including capillary bronchitis)** (91).
    *(*a*) Bronchopneumonia.
    *(*b*) Capillary bronchitis.
101. **Pneumonia** (92).
    (*a*) lobar.
    (*b*) not otherwise defined.
102. **Pleurisy** (93).
103. **Congestion and hemorrhagic infarct of the lung** (94).
104. **Gangrene of the lung** (95).
105. **Asthma** (96).
106. **Pulmonary emphysema** (97).
107. **Other diseases of the respiratory system** (98) **(tuberculosis excepted).**
    (*a*) Chronic interstitial pneumonia, including occupational diseases of the lung.
    (*b*) Diseases of the mediastinum.
    (*c*) Diseases not included under (*a*) or (*b*).

VI. — Diseases of the Digestive System

108A. *Diseases of the teeth and gums* (99).
108B. **Other Diseases of the mouth and annexa** (99).
109. **Diseases of the pharynx and tonsils (including adenoid vegetations)** (100).
    *(*a*) Adenoid vegetations.
    *(*b*) Others under this title.
110. **Diseases of the esophagus** (101).
111. **Ulcer of the stomach and duodenum** (102).
    (*a*) Ulcer of the stomach.
    (*b*) Ulcer of the duodenum.
112. **Other diseases of the stomach (cancer excepted)** (103).
113. **Diarrhea and enteritis** (under 2 years of age) (104).
114. **Diarrhea and enteritis** (2 years and over) (105).
115. **Ankylostomiasis** (106).
116. **Diseases due to other intestinal parasites** (107).
    (*a*) Cestodes (hydatids of the liver excepted).
    (*b*) Trematodes.
    (*c*) Nematodes (other than ankylostoma).

(*d*) Coccidia.
(*e*) Other parasites specified.
(*f*) Undefined parasites

117. Appendicitis and typhlitis (108).
118. Hernia, intestinal obstruction (109).
(*a*) Hernia.
(*b*) Intestinal obstruction.

119A *Diseases of the anus and stercoral fistulæ.*
119B. Other diseases of the intestines (110).
120 Acute yellow atrophy of the liver (111).
121. Hydatid tumor of the liver (112).
122. Cirrhosis of the liver (113).
(*a*) specified as alcoholic.
(*b*) not specified as alcoholic.

123 Biliary calculi (114).
124. Other diseases of the liver (115).
125. Diseases of the pancreas (116).
126. Peritonitis of unstated origin (117).
127. Other diseases of the digestive system (cancer and tuberculosis excepted) (118).

VII. — Non-Venereal Diseases of the Genito-urinary System and Annexa

128. Acute nephritis (including unspecified under 10 years of age) (119).
129. Chronic nephritis (including unspecified 10 years and over) (120).
130. Chyluria (121).
131. Other diseases of the kidneys and annexa (diseases of the kidneys in pregnancy excepted) (122).
132. Calculi of the urinary passages (123).
133. Diseases of the bladder (124).
134. Diseases of the urethra, urinary abscess, etc. (125).
(*a*) Stricture of the urethra.
(*b*) Others under this title.

135. Diseases of the prostate (126).
136 Non-venereal diseases of the male genital organs (127).
137. Cysts and other benign tumors of the ovary (131).
138. Salpingitis and pelvic abscess (132).
139. Benign tumors of the uterus (129).
140. Non-puerperal uterine hemorrhage (128).
141A. *Metritis* (130).
141B. Other diseases of the female genital organs (130)
142. Non-puerperal diseases of the breast (cancer excepted) (133).

VIII. — The Puerperal State

143A. *Normal Childbirth.*
143B. Accidents of pregnancy (134).
(*a*) Abortion.
(*b*) Ectopic gestation.
(*c*) Other accidents.

144. Puerperal hemorrhage (135).
145. Other accidents of childbirth (136).
 *(*a*) Cesarean section.
 *(*b*) Other surgical operations and instrumental delivery.
 *(*c*) Others under this title.
146. Puerperal septicemia (137).
147. Puerperal phlegmasia alba dolens, puerperal embolism, or sudden death in the puerperium (139).
148 Puerperal albuminuria and convulsions (138).
149. Following childbirth (not otherwise defined) (140).
150. Puerperal diseases of the breast (141).

IX. — Diseases of the Skin and of the Cellular Tissue

151. Gangrene (142).
152. Furuncle (143).
153. Phlegmon, acute abscess (144).
154. Other diseases of the skin and annexa (145).
 (*a*) *Trichophytosis.*
 (*b*) *Scabies.*
 (*c*) *Other diseases.*

X. — Diseases of the Bones and of the Organs of Locomotion

155. Diseases of the bones (tuberculosis and rickets excepted) (146).
156. Diseases of the joints (tuberculosis and rheumatism excepted) (147).
157. Amputations (148).
158. Other diseases of the organs of locomotion (149).

XI. — Malformations

159. Congenital malformations (150).
 (stillbirths not included).
 *(*a*) Hydrocephalus.
 *(*b*) Congenital malformations of the heart.
 *(*c*) Others under this title.

XII. — Early Infancy

160A. *Nurslings discharged from hospital without disease.*
160B. Congenital debility, icterus, and sclerema (151).
161. Premature birth; Injury at birth (151).
 *(*a*) Premature birth.
 *(*b*) Injury at birth.
162. Other diseases peculiar to early infancy (152).
163. Lack of care (153).

XIII. — Old Age

164. Senility (154).

XIV. — External Causes

165. Suicide by solid or liquid poisons) corrosive substances excepted) (155).
166. Suicide by corrosive substances (155).
167. Suicide by poisonous gas (168).

168. Suicide by hanging or strangulation (157).
169. Suicide by drowning (158).
170. Suicide by firearms (159).
171. Suicide by cutting or piercing instruments (160).
172. Suicide by jumping from high places (161).
173. Suicide by crushing (162).
174 Other suicides (163)
175. Poisoning by food (164).
176. Poisoning by venomous animals (165).
177. Other acute accidental poisonings (gas excepted) (165).
178. Conflagration (166).
179. Accidental burns (conflagration excepted) (167).
180. Accidental mechanical suffocation.
181. Accidental absorption of irrespirable or poisonous gas (168).
182. Accidental drowning (169).
183. Accidental traumatism by firearms (wounds of war excepted) (170).
184. Accidental traumatism by cutting or piercing instruments (171).
185. Accidental traumatism by fall (172).
186. Accidental traumatism in mines and quarries (173).
   *(*a*) Mines.
   *(*b*) Quarries.
187. Accidental traumatism by machines (174)
188. Accidental traumatism by other crushing (vehicles, railways, landslides, etc.) (175).
   *(*a*) Railroad accidents.
   *(*b*) Street car accidents.
   *(*c*) Automobile accidents.
   *(*d*) Aeroplane and balloon accidents.
   *(*e*) Injuries by other vehicles.
   *(*f*) Landslide, other crushing.
189. Injuries by animals (not poisoning) (176).
190. Wounds of war.
191. Execution of civilians by belligerent armies.
192A. *Fatigue.*
192B. Starvation (deprivation of food or water) (177).
193. Excessive cold (178).
194 Excessive heat (179).
195. Lightning (180).
196. Other accidental electric shocks (181).
197. Homicide by firearms (182).
198. Homicide by cutting or piercing instruments (183).
199. Homicide by other means (184).
200 Infanticide (murder of infants less than one year of age).
201A. *Dislocations.*
201B. Sprains.
201C. Fracture (cause not specified) (185).
202. Other external violence (cause specified) (186).
203. Other external violence (cause not specified) (187).

*[This title to be omitted when homicides are shown by ages under Titles 197–199.]

XV. — Ill-Defined Diseases

204. **Sudden death** (188).
205A. **Cause of death not specified or ill-defined** (189).
  *(*a*) Ill-defined.
  *(*b*) Not specified or unknown.
205B. *No disease, simulation.*

XVI.— Diseases Omitted As Having Caused Less Than 10 Deaths

206. **Diseases omitted as having caused less than 10 deaths.**

Suggestions to Physicians. — In reporting deaths from poisoning state the exact **name of poison,** whether the poisoning was **chronic and due to occupation,** and also please be particularly careful to see that the **Special Occupation and Industry** are fully stated. If the occupation stated on the certificate is not that in which the poisoning occurred, add the latter in connection with the statement of cause of death, *e g*, **"Chronic occupational phosphorus necrosis (dipper, match factory, white phosphorus)."** Give full details, including pathologic conditions contributory to death. Following is a list of Industrial Poisons (*Bull. Bureau of Labor*, May, 1912) to which the attention of physicians practicing in industrial communities should be especially directed:

Acetaldehyde,
Acridine,
Acrolein,
Ammonia,
Amyl acetate,
Amyl alcohol,
Aniline,
Aniline dyestuffs (name),
Antimony compounds (name),
Arsenic compounds (name),
Arseniureted hydrogen,
Benzine,
Benzol,
Carbon dioxide,
Carbon disulphide,
Carbon monoxide (coal vapor, illuminating water gas, producer gas),
Chloride of lime,
Chlorine,
Chlorodinitrobenzol,
Chloronitrobenzol,
Chromium compounds (name),
Cyanogen compounds (name),
Diazomethane,
Dimethyl sulphate,
Dinitrobenzol,
Formaldehyde,
Hydrochloric acid,
Hydrofluoric acid,
Lead (57),
Manganese dioxide,
Mercury,
Methyl alcohol,
Methyl bromide,
Nitraniline,
Nitrobenzol,
Nitroglycerin,
Nitronaphthalene,
Nitrous gases,
Oxalic acid,
Petroleum,
Phenol,
Phenylhydrazine,
Phosgene,
Phosphorus (yellow or white),
Phosphorus sesquisulphide,
Phosphureted hydrogen,
Picric acid,
Pyridine,
Sulphur chloride,
Sulphur dioxide,
Sulphureted hydrogen,
Sulphuric acid,
Tar,
Turpentine oil.

Not all substances in the preceding list are likely to be reported as causes of death, but the physician should be familiar with it in order to recognize, and to report, if required, cases of illness, and should also be on the alert to discover new forms of industrial poisoning not heretofore recognized. In the Bulletin cited full details may be found as to the branches of industry in which the poisoning occurs, mode of entrance into the body, and the symptoms of poisoning. Attention should also be called to industrial infection, *e g.*, Anthrax (27), and the influence of gases and vapors, dust, or unhygienic industrial environment.

In Section VIII the term **puerperal** is intended to include pregnancy, parturition, and lactation. Whenever parturition or miscarriage has occurred within one month before the death of the patient, the fact should be certified, even though childbirth may not have contributed to the fatal issue. Whenever a woman of childbearing age, especially if married, is reported to have died from a disease which might have been puerperal, the local registrar should require an explicit statement from the reporting physician as to whether the disease was or was not puerperal in character. The following diseases and symptoms are of this class:

Abscess of the breast,
Albuminuria,
Cellulitis,
Coma,
Convulsions,
Eclampsia,
Embolism,
Endometritis,
Gastritis,
Hemmorrhage (uterine or unqualified),
Lymphangitis,
Metritis,
Metroperitonitis,
Metrorrhagia,
Nephritis,
Pelviperitonitis,
Peritonitis,
Phlegmasia alba dolens,
Phlebitis,
Pyemia,
Septicemia,
Sudden death,
Tetanus,
Thrombosis,
Uremia.

Physicians are requested always to write **Puerperal** before the above terms and others that might be puerperal in character, or to add in parentheses (**Not puerperal**), so that there may be no possibility of error in the complication of the mortality statistics; also to respond to the requests of the local registrars for additional information when, inadvertently, the desired data are omitted. The value of such statistics can be greatly improved by cordial coöperation between the medical profession and the registration officials. If a physician will not write the true statement of puerperal character on the certificate, he may privately communicate that fact to the local or state registrar, or write the number of the International List under which the death should be compiled, *e.g.*, " Peritonitis (146)."

Coroners, medical examiners, and physicians who certify to deaths from violent causes, should always clearly indicate the fundamental distinction of whether a death was due to Accident, suicide, or homicide; and then state the means or instrument of death. The qualification " *probably* " may be added when necessary.

It is highly desirable to reduce as much as possible the reports of deaths from " ill-defined diseases."

If physicians will familiarize themselves with the nature and purposes of the International List, and will coöperate with the registration authorities in giving additional information so that returns can be properly classified, the number of deaths compiled under this group will rapidly diminish, and the statistics will be more creditable to the office that compiles them and more useful to the medical profession and for sanitary purposes.

Sometimes it may be extremely difficult or impossible to determine definitely the cause of death in some cases, even if a post-mortem be granted. If the physician is absolutely unable to satisfy himself in this respect, it is better for him to write unknown than merely to guess at the cause. It will be helpful if he can specify a little further, as unknown disease (which excludes external causes), or unknown chronic disease (which excludes the acute infective diseases), etc Even the ill-defined causes included under this head are at least useful to a limited degree, and are preferable to no attempt at statement. Some of the old "chronics," which well-informed physicians are coming less and less to use, are the following: *Asphyxia; Asthenia; Bilious fever; Cachexia; Catarrhal fever; Collapse; Coma; Congestion; Cyanosis; Debility; Delirium; Dentition; Dyspnea; Exhaustion, Fever; Gastric fever; Heart failure; Laparotomy; Marasmus; Paralysis of the heart; Surgical shock;* and *Teething*. In many cases so reported the physician could state the disease (not mere symptom or condition) causing death.

LIST OF UNDESIRABLE TERMS

UNDESIRABLE TERM (It is understood that the term criticised is in the *exact form* given below, *without further explanation or qualification*)	REASON WHY UNDESIRABLE, AND SUGGESTION FOR MORE DEFINITE STATEMENT OF CAUSE OF DEATH.
(1)	(2)
" *Abscess*," " *Abscess of brain*," " *Abscess of lung*," etc.	Was it tuberculous or due to other infection? Traumatic? The return of " Abscess," unqualified, is worthless State cause (in which case the fact of " abscess " may be quite unimportant) and location.
"*Accident*," "*Injury*," "*External causes*," " *Violence* " Also more specific terms, as "*Drowning*," "*Gun-shot*," which might be either accidental, suicidal, or homicidal	Impossible to classify satisfactorily Always state (1) whether **Accidental, Suicidal,** or **Homicidal;** and (2) **Means of injury** (*e g* , Railroad accident). The lesion (*e.g* , Fracture of skull) may be added, but is of secondary importance for general mortality statistics.
" *Acidosis* "	Cause of the acidosis? If diabetic, write *Acidosis (diabetic)*; if not diabetic, write *Acidosis (non-diabetic)*
" *Anasarca*," " *Ascites* " . .	See " *Dropsy* "
" *Atrophy*," " *Asthenia*," "*Debility*," "*Decline*," "*Exhaustion*," "*Inanition*," " *Weakness*," and other vague terms.	Frequently covers tuberculosis and other definite causes Name the disease causing the condition.
" *Blood poisoning* ". .	See " *Septicemia* " Syphilis?

LIST OF UNDESIRABLE TERMS

Undesirable Term.	Reason Why Undesirable, and Suggestion for More Definite Statement of Cause of Death.
(1)	(2)
"*Bright's disease*" . .	Was it acute or chronic and, if acute, what was the cause? Was it puerperal?
"*Bright's disease,*" *acute* . .	What was the cause of the acute "*Bright's disease*"? If it appeared as a complication or sequela of some other disease or abnormal condition, state nature of the same Was it puerperal? When no cause can be ascribed write **Bright's disease, acute** (cause unknown).
"*Bronchopneumonia*"	When this condition terminates measles, whooping cough, or some other disease, the primary disease should always be stated When bronchopneumonia is itself primary, the certificate should be written **Bronchopneumonia** (primary).
"*Burns*"	How received? If due to conflagration, as burning house, prairie fire, etc , so state Also state whether accidental, suicidal or homicidal
"*Cancer,*" "*Carcinoma,*" "*Sarcoma,*" etc	In all cases the **organ or part first affected by cancer should be specified.**
"*Catarrh*"	Term best avoided, if possible.
"*Cardiac insufficiency,*" "*Cardiac degeneration,*" "*Cardiac weakness,*" etc	See "*Heart disease*" and "*Heart failure.*"
"*Cardiac dilatation*".	Do not report when a mere terminal condition. State cause
"*Cellulitis*"	See "*Abscess,*" "*Septicemia.*"
"*Cerebral softening*" . . .	What was the cause? If due to arteriosclerosis, cerebral hemorrhage, embolism, thrombosis, traumatism, or any other discernible cause state nature of the same.
"*Cerebrospinal meningitis*"	See "*Meningitis*"
"*Congestion,*" "*Congestion of bowels,*" "*Congestion of brain,*" "*Congestion of kidneys,*" "*Congestion of lungs,*" etc.	Alone, the word "*congestion*" is worthless, and in combination it is almost equally undesirable If the disease amounted to *inflammation*, use the proper term (lobar pneumonia, chronic nephritis, enteritis, etc), merely passive congestion should not be reported as a cause of death. **State the primary cause.**
"*Convulsions,*" "*Eclampsia,*" "*Fit,*" or "*Fits.*"	"It is hoped that this indefinite term ["*Convulsions*"] will henceforth be restricted to those cases in which the true cause of that *symptom* can not be ascertained "*Fit.* — This is an objectionable term, it is indiscriminately applied to epilepsy, convulsions and apoplexy in different parts of the country" — *Dr. Farr, in First Rep. Reg-Gen*, 1839.

LIST OF UNDESIRABLE TERMS

Undesirable Term	Reason Why Undesirable, and Suggestion for More Definite Statement of Cause of Death.
(1)	(2)
"*Croup*".	"*Croup*" is a most pernicious term from a public health point of view, is not contained in any form in the London or Bellevue Nomenclatures, and should be entirely disused Write **Diphtheria** when this disease is the cause of death.
"*Dentition*," "*Teething*". . .	State **disease causing death.**
"*Disease*," "*Trouble*," or "*Complaint*" of (*any organ*), *e g*, "*Lung trouble*," "*Kidney complaint*," "*Disease of brain*," etc	Name the **disease**, *e g*, **Lobar pneumonia, Tuberculosis of lungs, Chronic interstitial nephritis, Syphilitic gumma of brain**, etc.
"*Dropsy*".	"'*Dropsy*' should never be returned as the cause of death without particulars as to its probable origin, *e g*, in disease of the heart, liver, kidneys, etc" — *Registrar-General* Name the disease causing (the *dropsy* and) **death.**
"*Edema of glottis*"	What was the cause? If due to disease of any part, specify, or if to injury state whether accidental, suicidal or homicidal and the means of injury.
"*Edema of lungs*"	Usually terminal Name the disease causing the condition.
"*Extravasation of urine*" .	What was the cause? If due to a diseased condition of any part or followed an operation or injury, define the primary condition, if known If of traumatic origin, state whether accidental, suicidal or homicidal and the means or instrument of death, *e g*., automobile, revolver, etc.
"*Fever*".	Name the disease, as **Typhoid fever, Lobar pneumonia, Malaria**, etc, in which the **"fever"** occurs
"*Fracture*," "*Fracture of skull*," etc.	Indefinite; the principle of classification for general mortality statistics is *not* the lesion but (1) the nature of the violence that produced it (**Accidental, Suicidal, Homicidal**), and (2) the **Means of injury.**
"*Gangrene of intestines*". . . .	What was the cause? If due to embolism, mechanical obstruction or paralysis, state as clearly as possible the nature of the affection. If due to violence, state the means or instrument of injury, *e g*, automobile, revolver, etc, and whether **accidental, suicidal or homicidal.**
"*Gastritis*," "*Gastric catarrh*," "*Acute indigestion*."	Frequently worthless as a statement of the actual cause of death, the terms should not be loosely used to cover almost any fatal affection with irritation of stomach. Gastroenteritis? Acute or chronic, and cause?
"*General decay*," etc..	See "*Old age*"
"*General sclerosis*".	Was it general sclerosis of the spinal cord, or **General arteriosclerosis?**

LIST OF UNDESIRABLE TERMS

UNDESIRABLE TERM.	REASON WHY UNDESIRABLE, AND SUGGESTION FOR MORE DEFINITE STATEMENT OF CAUSE OF DEATH.
(1)	(2)
"*Heart disease*," "*Heart trouble*," even "*Organic heart trouble*"	The exact form of the cardiac affection, as **Mitral regurgitation, Aortic stenosis**, or, less precisely, as **Valvular heart disease**, should be stated.
"*Heart failure*," "*Cardiac weakness*," "*Cardiac asthenia*," "*Cardiac exhaustion*," "*Paralysis of the heart*," etc.	"*Heart failure*" is a recognized synonym, even among the laity, for ignorance of the cause of death on the part of the physician If the physician can make no more definite statement, it must be compiled among the class of ill-defined diseases (*not* under heart disease).
"*Hemorrhage*," "*Hemoptysis*," "*Hemorrhage of lungs*."	Frequently mask tuberculosis or deaths from injuries (traumatic hemorrhage), **Puerperal hemorrhage**, or hemorrhage after operation for various conditions What was the **cause** and **location** of the hemorrhage? If from violence, state fully (p 11).
"*Homicide*".	State means employed, *e g*, poison, revolver, etc.
"*Hydrocephalus*".	"It is desirable that deaths from hydrocephalus of tuberculous origin should be definitely assigned in the certificate to **Tuberculous meningitis**, so as to distinguish them from deaths caused by simple inflammation or other disease of the brain or its membranes. **Congenital hydrocephalus** should always be returned as such" — *Registrar-General.*
"*Hydrocephalus, acute*".	State primary cause of condition If tuberculous meningitis, so state If not tuberculous write **Hydrocephalus, acute** (not tuberculous).
"*Hysterectomy*"	See "*Operation.*"
"*Infantile asthenia*," "*Infantile atrophy*," "*Infantile debility*," etc	See "*Atrophy*"
"*Infantile paralysis*"	This term is sometimes used for paralysis of infants caused by instrumental delivery, etc The importance of the disease in its recent endemic and epidemic prevalence in the United States makes the exact and unmistakable expressions **Acute anterior poliomyelitis** or **Infantile paralysis (acute anterior poliomyelitis)** desirable.
"*Inflammation*"...........	Of what organ or part of the body? Cause?
"*Laparotomy*".	See "*Operation.*"
"*Malignant*," "*Malignant disease.*"	Should be restricted to use as qualification for neoplasms, see Tumor.
"*Malnutrition*".	See "*Atrophy*"
"*Membranous laryngitis*"..	State clearly whether diphtheritic or not.

LIST OF UNDESIRABLE TERMS

Undesirable Term	Reason Why Undesirable, and Suggestion for More Definite Statement of Cause of Death
(1)	(2)
"*Meningitis*," "*Cerebral meningitis*," "*Cerebrospinal meningitis*," "*Spinal meningitis*."….	Only three terms should ever be used to report deaths from **Cerebrospinal fever,** *synonyms*, **Epidemic cerebrospinal meningitis, meningococcus meningitis,** and they should be written as above and in no other way It matters not in the use of the latter term whether or not the disease be actually *epidemic* in the locality A single sporadic case should be so reported. No one can intelligently classify such returns as are given in the margin Mere terminal or symptomatic meningitis should not be entered at all as a cause of death, name the disease in which it occurred. **Tuberculous meningitis** should be reported as such
"*Natural causes*" ……	This statement eliminates external causes, but is otherwise of little value **What disease (probably) caused death?**
"*Nephritis*"..	Was it acute or chronic and, if acute, what was the cause? Was it puerperal?
"*Nephritis, acute*" ….	What was the cause of the acute nephritis? If it appeared as a complication or sequela of some other disease or abnormal condition, state nature of the same Was it puerperal? When no cause can be ascribed write **Acute nephritis** (cause unknown).
"*Old age*," "*Senility*," etc …	Too often used for deaths of elderly persons who succumbed to a definite disease. **Name the disease causing death.**
"*Operation*," "*Surgical operation*," "*Surgical shock*," "*Amputation*," "*Hysterectomy*," "*Laparotomy*," etc.	All these are entirely indefinite and unsatisfactory — unless the surgeon desires his work to be held primarily responsible for the death. Name the **disease, abnormal condition,** or form of external violence (**Means of death; accidental, suicidal,** or **homicidal?**), for which the operation was performed If death was due to an anesthetic (**chloroform, ether,** etc), state that fact and the name of the anesthetic.
"*Paralysis*," "*General paralysis*," "*Paresis*," "*General paresis*," "*Palsy*," etc.	The vague use of these terms should be avoided, and the precise form stated, as **Acute ascending paralysis, Paralysis agitans, Bulbar paralysis,** etc. Write **General paralysis of the insane** in full, not omitting any part of the name; this is essential for satisfactory compilation of this cause. Distinguish **Paraplegia** and **Hemiplegia;** and in the latter, when a sequel of **Apoplexy** or **Cerebral hemorrhage,** report the primary cause.
"*Parotiditis (parotitis)*"….	State definitely whether mumps or not.
"*Perforation or rupture of a part*"	State cause of perforation or rupture, *e.g*, ulcer, injury by automobile, revolver, etc., and, in case of injury, state whether **accidental, suicidal** or **homicidal.**

LIST OF UNDESIRABLE TERMS

Undesirable Term	Reason Why Undesirable, and Suggestion for More Definite Statement of Cause of Death
(1)	(2)
"*Peritonitis*"	"Whenever this condition occurs — either as a consequence of **Hernia, Perforating ulcer of the stomach or bowel** [**Typhoid fever?**], **Appendicitis,** or **Metritis** (puerperal or otherwise), or else as an extension of morbid processes from other organs [Name the disease], the fact should be mentioned in the certificate " — *Registrar-General.* Always specify **Puerperal peritonitis** in cases resulting from abortion, miscarriage, or labor at full term Always state if due to **tuberculosis** or **cancer.** When traumatic, report **means of injury** and whether **accidental, suicidal, or homicidal.**
"*Pleurisy*"	State the cause, as lobar pneumonia, acute rheumatism, tuberculosis, traumatism If due to violence, state the means or instrument of injury, *e g*, automobile, revolver, etc, and whether **accidental, suicidal,** or **homicidal.**
"*Pneumonia,*" "*Typhoid pneumonia*"	"*Pneumonia,*" without qualification, is indefinite; it should be clearly stated either as **Bronchopneumonia** or **Lobar pneumonia.** The term **Croupous pneumonia** is also clear. "The term '*Typhoid pneumonia*' should never be employed, as it may mean either Enteric fever [**Typhoid fever**] with pulmonary complications, on the one hand, or Pneumonia with so-called typhoid symptoms on the other." — *Registrar-General* When lobar pneumonia or bronchopneumonia occurs in the course of or following a disease, the primary cause should be entered first, with duration, and the lobar pneumonia or bronchopneumonia be entered beneath as the contributory cause, with duration. Do not report "*Hypostatic pneumonia*" or other mere terminal conditions as causes of death when the disease causing death can be ascertained.
"*Ptomain poisoning,*" "*Autointoxication,*" "*Toxemia,*" etc.	These terms are used very loosely and it is impossible to compile statistics of value unless greater precision can be obtained. They should not be used when merely descriptive of symptoms or conditions arising in the course of diseases, but the **disease causing death** should alone be named. "Ptomain poisoning" should be restricted to deaths resulting from the development of putrefactive alkaloids or other poisons in food, and the food should be named, as **Ptomain poisoning (mussels),** etc.
"*Pulmonary congestion,*" "*Pulmonary hemorrhage.*"	See "*Congestion,*" "*Hemorrhage.*"
"*Pyemia*"	See "*Septicemia*"
"*Salpingitis*"	To what was the salpingitis due? If of gonorrheal, syphilitic, puerperal or traumatic origin, state the facts as fully as possible.
"*Sclerosis*"	Was it sclerosis of the spinal cord, or General arteriosclerosis?

LIST OF UNDESIRABLE TERMS

Undesirable Term.	Reason Why Undesirable, and Suggestion for More Definite Statement of Cause of Death
(1)	(2)
"*Septicemia*," "*Sepsis*," "*Septic infection*," etc.	Always state **cause** of this condition, and, if localized, **part affected.** Puerperal? Traumatic (see p 11)?
"*Shock*" (post-operative)...	See "*Operation*."
"*Specific*"	The word *specific* should never be used without further explanation It may signify *syphilitic*, *tuberculosis*, *gonorrheal*, *diphtheritic*, etc. **Name the disease.**
"*Stricture of esophagus*" ..	What was the cause of the stricture? If due to congenital stenosis, cicatricial contraction or tumor of esophagus, to pressure from surrounding parts or other discernible cause, state exact nature of same
"*Suicide*".. .	State means employed, *e g*, **drowning, gunshot,** etc.
"*Tabes mesenterica*," "*Tabes*"	"The use of this term ["*Tabes mesenterica*"] to describe tuberculous disease of the peritoneum or intestines should be discontinued, as it is frequently used to denote various other wasting diseases which are not tuberculous **Tuberculous peritonitis** is the better term to employ when the condition is due to tubercle" — *Registrar-General.* **Tabes dorsalis** should not be abbreviated to "*Tabes*"
"*Teething*"...............	See "*Dentition*."
"*Toxemia*"..	See "*Ptomain poisoning*"
"*Tuberculosis*"	The organ or part of the body affected should always be stated, as **Tuberculosis of the lungs, Tuberculosis of the spine, Tuberculous meningitis, Acute general miliary tuberculosis,** etc.
"*Tumor*," "*Neoplasm*," "*New growth*"	These terms should never be used without the qualifying words **Malignant, Nonmalignant,** or **Benign.** If malignant, they belong under **Cancer,** and should preferably be so reported, or under the more exact terms **Carcinoma, Sarcoma,** etc In all cases the **organ or part affected** should be specified.
"*Uremia*"	Name the **disease causing death,** *i e*, the primary cause, not the mere terminal conditions or symptoms, and state the **duration of the primary cause.**
"*Uterine hemorrhage*"	See "*Hemorrhage*"

Some of the synonyms used for "typhoid fever." — The following is a partial list of terms which have been used to describe typhoid fever:

Abdominal fever,
Abdominal typhoid,
Abdominal typhus,
Abortive typhoid,
Ambulant typhoid,
Cerebral typhoid,
Cerebral typhus,
Continued fever,
Enteric fever,
Enterica,
Gastroenteric fever,
Hæmorrhagic typhoid fever,
Ileotyphus,
Intermittent typhoid fever,
Malignant typhoid fever,
Mountain fever,
Paratyphoid fever.
Paratyphus,
Posttyphoid abscess,
Rheumatic typhoid fever,
Typhobilious fever,
Typhoenteritis,
Typhogastric fever,
Typhoid fever,
Typhoid malaria,
Typhoid meningitis,
Typhoid stupor,
Typhoid ulcer,
Typhomalaria,
Typhomalarial fever,
Typhoperitonitis,
Typhus,
Typhus abdominalis.

This shows the great need of standardization.

Joint causes of death. — The Bureau of the Census in 1914 published an "Index of Joint Causes of Death," which showed the proper method of assignment to the preferred title of causes of death when two causes are simultaneously reported. This index, alphabetically arranged, was very useful. Physicians sometimes report two or more causes of death upon the death-certificate. This may be historically true as one disease may be a complication of the other. For statistical purposes, however, only one cause can be tabulated for each death. Out of the two or more causes given one must be selected, and it is a matter of great importance how this is done. For some years the attempt has been made to separate the diseases reported into the primary cause and secondary cause. As this gave rise to some uncertainty as to which was which, the form of the Revised U. S.

Standard Certificate of Death asks for "The Cause of Death" and for "The Contributory Cause (Secondary)." The English, French and Germans have laid down certain rules for making the proper selections. In general, it may be said that the primary cause is the real, or underlying, cause of death (the primary affection with respect to time and causation).

At the present time (1922) the Bureau of the Census has not issued an Index of Joint Causes based on the International List of 1920.

Occupation. — During recent years the study of the relation between occupation and disease has received much attention, and this study has shown the very great importance of the industrial hazard. Fundamental to such a study is a proper classification of occupations. The list which follows was published by the Bureau of the Census in 1921. It is taken from a report entitled "Classified Index to Occupations," a book of 173 pages.

This classification contains 224 main groups, 95 of which are subdivided, making a total of 572 separate groups. The industrial field is divided into eight general divisions, and each occupation has been "classified in that part of the industrial field in which it is most commonly pursued." Clerical occupations are classified apart. The classification is along *occupational* rather than *industrial* lines. In the table each occupation is indicated by a symbol consisting of three figures.

LIST OF OCCUPATIONS AND OCCUPATION GROUPS WITH THEIR SYMBOLS.

Symbol.	Occupation and Occupation Group.
	AGRICULTURE, FORESTRY, AND ANIMAL HUSBANDRY.
	Dairy farmers, farmers, and stock raisers
0 0 2	Dairy farmers
0 0 0	Farmers, general farms
0 0 4	Farmers, turpentine farms
0 0 6	Stock raisers
	Dairy farm, farm, and stock farm laborers
0 0 8	Dairy farm laborers
0 1 0	Farm laborers (home farm)
0 1 2	Farm laborers (working out)
0 1 4	Farm laborers (turpentine farm)
0 1 6	Stock herders, drovers, and feeders
	Dairy farm, farm, garden, orchard, etc., foremen
0 1 8	Dairy farm foremen
0 2 0	Farm foremen, general farms
0 2 2	Farm foremen, turpentine farms
0 2 4	Farm foremen, stock farms
0 2 6	Garden and greenhouse foremen
0 2 8	Orchard, nursery, etc , foremen
0 3 0	Fishermen and oystermen
0 3 2	Foresters, forest rangers, and timber cruisers
	Gardeners, florists, fruit growers, and nurserymen
0 3 4	Florists
0 3 6	Fruit growers
0 3 8	Gardeners
0 4 0	Landscape gardeners
0 4 2	Nurserymen
	Garden, greenhouse, orchard, and nursery laborers
0 4 4	Cranberry bog laborers
0 4 6	Garden laborers
0 4 8	Greenhouse laborers
0 5 0	Orchard and nursery laborers
	Lumbermen, raftsmen, and woodchoppers
0 5 2	Foremen and overseers
0 5 4	Inspectors, scalers, and surveyors
0 5 6	Teamsters and haulers
0 5 8	Other lumbermen, raftsmen, and woodchoppers
	Owners and managers of log and timber camps
0 6 0	Managers and officials
0 6 2	Owners and proprietors
	Other agricultural and animal husbandry pursuits
0 6 3	Apiarists
0 6 4	Corn shellers, hay balers, grain threshers, etc.
0 6 5	Ditchers (farm)
0 6 6	Irrigators and ditch tenders
0 6 7	Poultry raisers
0 6 8	Poultry yard laborers
0 6 9	Other and not specified pursuits

LIST OF OCCUPATIONS AND OCCUPATION GROUPS WITH THEIR SYMBOLS — Continued.

Symbol.	Occupation and Occupation Group.
	EXTRACTION OF MINERALS.
	Foremen, overseers, and inspectors
0 7 0	Foremen and overseers
0 7 2	Inspectors
	Operators, officials, and managers
0 7 4	Managers
0 7 6	Officials
0 7 8	Operators
0 8 0	Coal mine operatives
0 8 2	Copper mine operatives
0 8 4	Gold and silver mine operatives
0 8 6	Iron mine operatives
	Operatives in other and not specified mines
0 8 8	Lead and zinc mine operatives
0 9 0	Other specified mine operatives
0 9 2	Not specified mine operatives
0 9 4	Quarry operatives
	Oil, gas, and salt well operatives
0 9 6	Oil and gas well operatives
0 9 8	Salt well and works operatives
	MANUFACTURING AND MECHANICAL INDUSTRIES.
	Apprentices to building and hand trades
1 0 0	Blacksmiths' apprentices
1 0 2	Boiler makers' apprentices
1 0 4	Cabinetmakers' apprentices
1 0 6	Carpenters' apprentices
1 0 8	Coopers' apprentices
1 1 0	Electricians' apprentices
1 1 2	Machinists' apprentices
1 1 4	Masons' apprentices
1 1 6	Painters', glaziers', and varnishers' apprentices
1 1 8	Paper hangers' apprentices
1 2 0	Plasterers' apprentices
1 2 2	Plumbers' apprentices
1 2 4	Roofers' and slaters' apprentices
1 2 6	Tinsmiths' and coppersmiths' apprentices
	Apprentices to dressmakers and milliners
1 2 7	Dressmakers' apprentices
1 2 8	Milliners' apprentices
	Apprentices, other
1 2 9	Architects', designers', and draftmen's apprentices
1 3 0	Jewelers', watchmakers', goldsmiths', and silversmiths' apprentices
1 3 1	Printers' and bookbinders' apprentices
1 3 2	Other apprentices
1 3 4	Bakers
	Blacksmiths, forgemen, and hammermen
1 3 6	Blacksmiths
1 3 8	Forgemen, hammermen, and welders

LIST OF OCCUPATIONS AND OCCUPATION GROUPS WITH THEIR SYMBOLS — Continued.

Symbol.	Occupation and Occupation Group.
	MANUFACTURING, ETC. — Continued.
1 4 0	Boiler makers
1 4 2	Brick and stone masons
1 4 4	Builders and building contractors
1 4 6	Cabinetmakers
1 4 8	Carpenters
1 5 0	Compositors, linotypers, and typesetters
1 5 2	Coopers
1 5 4	Dressmakers and seamstresses (not in factory)
1 5 6	Dyers
1 5 8	Electricians
	Electrotypers, stereotypers, and lithographers
1 6 0	Electrotypers and stereotypers
1 6 2	Lithographers
	Engineers (stationary), cranemen, hoistmen, etc.
1 6 4	Engineers (stationary)
1 6 6	Cranemen, derrickmen, hoistmen, etc.
1 6 8	Engravers
	Filers, grinders, buffers, and polishers (metal)
1 7 0	Buffers and polishers
1 7 2	Filers
1 7 4	Grinders
1 7 6	Firemen (except locomotive and fire department)
1 7 8	Foremen and overseers (manufacturing)
	Furnace men, smelter men, heaters, pourers, etc.
1 8 0	Furnace men and smelter men
1 8 2	Heaters
1 8 4	Ladlers and pourers
1 8 6	Puddlers
1 8 8	Glass blowers
	Jewelers, watchmakers, goldsmiths, and silversmiths
1 9 0	Goldsmiths and silversmiths
1 9 2	Jewelers and lapidaries (factory)
1 9 4	Jewelers and watchmakers (not in factory)
	Laborers (n. o. s.[1])
1 9 6	Building, general, and not specified laborers
	Chemical and allied industries
1 9 8	Fertilizer factories
2 0 0	Paint and varnish factories
2 0 2	Powder, cartridge, dynamite, fuse, and fireworks factories
2 0 4	Soap factories
2 0 6	Other chemical factories
2 0 8	Cigar and tobacco factories
	Clay, glass, and stone industries
2 1 0	Brick, tile, and terra-cotta factories
2 1 2	Glass factories
2 1 4	Lime, cement, and artificial stone factories
2 1 6	Marble and stone yards
2 1 8	Potteries

[1] Not otherwise specified.

LIST OF OCCUPATIONS AND OCCUPATION GROUPS WITH THEIR SYMBOLS — Continued.

Symbol	Occupation and Occupation Group.
	MANUFACTURING, ETC. — Continued.
	Laborers (n. o. s.) — Continued.
	Clothing industries
2 2 0	Corset factories
2 2 2	Glove factories
2 2 4	Hat factories (felt)
2 2 6	Shirt, collar, and cuff factories
2 2 8	Suit, coat, cloak, and overall factories
2 3 0	Other clothing factories
	Food industries
2 3 2	Bakeries
2 3 4	Butter, cheese, and condensed milk factories
2 3 6	Candy factories
2 3 8	Fish curing and packing
2 4 0	Flour and grain mills
2 4 2	Fruit and vegetable canning, etc.
2 4 4	Slaughter and packing houses
2 4 6	Sugar factories and refineries
2 4 8	Other food factories
2 5 0	Harness and saddle industries
2 5 2	Helpers in building and hand trades
	Iron and steel industries
2 5 4	Agricultural implement factories
2 5 6	Automobile factories
2 5 8	Blast furnaces and steel rolling mills [1]
2 6 0	Car and railroad shops
2 6 2	Ship and boat building
2 6 4	Wagon and carriage factories
2 6 6	Other iron and steel factories [2]
2 6 8	Not specified metal industries
	Other metal industries
2 7 0	Brass mills
2 7 2	Clock and watch factories
2 7 4	Copper factories
2 7 6	Gold and silver factories
2 7 8	Jewelry factories
2 8 0	Lead and zinc factories
2 8 2	Tinware, enamel-ware, etc., factories
2 8 4	Other metal factories
	Lumber and furniture industries
2 8 6	Furniture factories
2 8 8	Piano and organ factories
2 9 0	Saw and planing mills [3]
2 9 2	Other woodworking factories
2 9 4	Paper and pulp mills
	Printing and publishing
2 9 6	Blank book, envelope, tag, paper bag, etc., factories
2 9 8	Printing, publishing, and engraving
3 0 0	Shoe factories
3 0 2	Tanneries

[1] Includes tin-plate mills. [2] Includes iron foundries.
[3] Includes "Box factories (wood)."

LIST OF OCCUPATIONS AND OCCUPATION GROUPS WITH THEIR SYMBOLS — Continued.

Symbol.	Occupation and Occupation Group
	MANUFACTURING, ETC. — Continued
	Laborers (n. o. s.) — Continued.
	Textile industries
304	Carpet mills
306	Cotton mills
308	Knitting mills
310	Lace and embroidery mills
312	Silk mills
314	Textile dyeing, finishing, and printing mills
316	Woolen and worsted mills
	Other textile mills
318	Hemp and jute mills
320	Linen mills
322	Rope and cordage factories
324	Sail, awning, and tent factories
326	Not specified, textile mills
	Other industries
328	Broom and brush factories
320	Button factories
332	Charcoal and coke works
334	Electric light and power plants
336	Electrical supply factories
338	Gas works
340	Leather belt, leather case, etc., factories
342	Liquor and beverage industries
344	Paper box factories
346	Petroleum refineries
348	Rubber factories
350	Straw factories
352	Trunk factories
354	Turpentine distilleries
356	Other miscellaneous industries
358	Other not specified industries
360	Loom fixers
	Machinists, millwrights, and toolmakers
362	Machinists
364	Millwrights
366	Toolmakers and die setters and sinkers
368	Managers and superintendents (manufacturing)
	Manufacturers and officials
370	Manufacturers
372	Officials
	Mechanics (n. o. s.[1])
374	Gunsmiths, locksmiths, and bellhangers
376	Wheelwrights
378	Other mechanics
380	Millers (grain, flour, feed, etc.)
382	Milliners and millinery dealers
	Molders, founders, and casters (metal)
384	Brass molders, founders, and casters
386	Iron molders, founders, and casters
388	Other molders, founders, and casters

[1] Not otherwise specified.

LIST OF OCCUPATIONS AND OCCUPATION GROUPS WITH THEIR SYMBOLS — Continued.

Symbol	Occupation and Occupation Group.
	MANUFACTURING, ETC. — Continued.
390	Oilers of machinery
	Painters, glaziers, varnishers, enamelers, etc.
392	Enamelers, lacquerers, and japanners
394	Painters, glaziers, and varnishers (building)
396	Painters, glaziers, and varnishers (factory)
398	Paper hangers
400	Pattern and model makers
	Plasterers and cement finishers
402	Cement finishers
404	Plasterers
406	Plumbers and gas and steam fitters
408	Pressmen and plate printers (printing)
410	Rollers and roll hands (metal)
412	Roofers and slaters
414	Sawyers
	Semiskilled operatives (n. o. s.[1]):
	Chemical and allied industries
416	Fertilizer factories
418	Paint and varnish factories
420	Powder, cartridge, dynamite, fuse, and fireworks factories
422	Soap factories
424	Other chemical factories
426	Cigar and tobacco factories
	Clay, glass, and stone industries
428	Brick, tile, and terra-cotta factories
430	Glass factories
432	Lime, cement, and artificial stone factories
434	Marble and stone yards
436	Potteries
	Clothing industries
438	Corset factories
440	Glove factories
442	Hat factories (felt)
444	Shirt, collar, and cuff factories
446	Suit, coat, cloak, and overall factories
448	Other clothing factories
	Food industries
450	Bakeries
452	Butter, cheese, and condensed milk factories
454	Candy factories
456	Fish curing and packing
458	Flour and grain mills
460	Fruit and vegetable canning, etc.
462	Slaughter and packing houses
464	Sugar factories and refineries
466	Other food factories
468	Harness and saddle industries
	Iron and steel industries
470	Agricultural implement factories
472	Automobile factories
474	Blast furnaces and steel rolling mills

[1] Includes tin-plate factories.

LIST OF OCCUPATIONS AND OCCUPATION GROUPS WITH THEIR SYMBOLS — Continued.

Symbol	Occupation and Occupation Group.
	MANUFACTURING, ETC. — Continued.
	Semiskilled operatives (n. o. s.) — Continued
476	Car and railroad shops
478	Ship and boat building
480	Wagon and carriage factories
482	Other iron and steel factories [1]
484	Not specified metal industries
	Other metal industries
486	Brass mills
488	Clock and watch factories
490	Copper factories
492	Gold and silver factories
494	Jewelry factories
496	Lead and zinc factories
498	Tinware, enamel-ware, etc., factories
500	Other metal factories
	Lumber and furniture industries
502	Furniture factories
504	Piano and organ factories
506	Saw and planing mills [2]
508	Other woodworking factories
510	Paper and pulp mills
	Printing and publishing
512	Blank book, envelope, tag, paper bag, etc., factories
514	Printing, publishing, and engraving
516	Shoe factories
518	Tanneries
	Textile industries
520	Carpet mills
522	Cotton mills
524	Knitting mills
526	Lace and embroidery mills
528	Silk mills
530	Textile dyeing, finishing, and printing mills
532	Woolen and worsted mills
	Other textile mills
534	Hemp and jute mills
536	Linen mills
538	Rope and cordage factories
540	Sail, awning, and tent factories
542	Not specified textile mills
	Other industries
544	Broom and brush factories
546	Building and hand trades
548	Button factories
550	Charcoal and coke works
552	Electric light and power plants
554	Electrical supply factories
556	Gas works
558	Leather belt, leather case, etc., factories
560	Liquor and beverage industries
562	Paper box factories

[1] Includes iron foundries. [2] Includes "Box factories (wood.)"

LIST OF OCCUPATIONS AND OCCUPATION GROUPS WITH THEIR SYMBOLS — Continued.

Symbol	Occupation and Occupation Group
	MANUFACTURING, ETC — Continued.
	Semiskilled operatives (n o s.[1]) — Continued.
5 6 4	Petroleum refineries
5 6 6	Rubber factories
5 6 8	Straw factories
5 7 0	Trunk factories
5 7 2	Turpentine distilleries
5 7 4	Other miscellaneous industries
5 7 6	Other not specified industries
5 7 8	Shoemakers and cobblers (not in factory)
	Skilled occupations (n o s[1])
5 8 0	Annealers and temperers (metal)
5 8 2	Piano and organ tuners
5 8 4	Wood carvers
5 8 6	Other skilled occupations
5 8 8	Stonecutters
5 9 0	Structural iron workers (building)
5 9 2	Tailors and tailoresses
	Tinsmiths and coppersmiths
5 9 4	Coppersmiths
5 9 6	Tinsmiths and sheet metal workers
5 9 8	Upholsterers
	TRANSPORTATION.
	Water transportation (selected occupations).
6 0 0	Boatmen, canal men, and lock keepers
6 0 2	Captains, masters, mates, and pilots
6 0 4	Longshoremen and stevedores
6 0 6	Sailors and deck hands
	Road and street transportation (selected occupations):
6 0 8	Carriage and hack drivers
6 1 0	Chauffeurs
6 1 2	Draymen, teamsters, and expressmen[2]
6 1 4	Foremen of livery and transfer companies
6 1 6	Garage keepers and managers
6 1 8	Hostlers and stable hands
	Laborers (garage, road, and street)
6 2 0	Garage
6 2 1	Road and street building and repairing
6 2 2	Street cleaning
6 2 4	Livery stable keepers and managers
6 2 6	Proprietors and managers of transfer companies
	Railroad transportation (selected occupations).
	Baggagemen and freight agents
6 2 8	Baggagemen
6 2 9	Freight agents

[1] Not otherwise specified.

[2] Teamsters in agriculture, forestry, and the extraction of minerals are classified with the other workers in those industries, respectively; and drivers for bakeries and laundries are classified with deliverymen in trade.

LIST OF OCCUPATIONS AND OCCUPATION GROUPS WITH THEIR SYMBOLS — Continued.

Symbol	Occupation and Occupation Group.
	TRANSPORTATION — Continued.
	Railroad transportation (selected occupations): — Continued.
6 3 0	Boiler washers and engine hostlers
6 3 2	Brakemen
6 3 4	Conductors (steam railroad)
6 3 6	Conductors (street railroad)
	Foremen and overseers
6 3 8	Steam railroad
6 3 9	Street railroad
	Laborers
6 4 0	Steam railroad
6 4 2	Street railroad
6 4 4	Locomotive engineers
6 4 6	Locomotive firemen
	Motormen
6 4 8	Steam railroad
6 4 9	Street railroad
	Officials and superintendents
6 5 0	Steam railroad
6 5 2	Street railroad
	Switchmen, flagmen, and yardmen
6 5 4	Switchmen and flagmen (steam railroad)
6 5 5	Switchmen and flagmen (street railroad)
6 5 6	Yardmen (steam railroad)
6 5 8	Ticket and station agents
	Express, post, telegraph, and telephone (selected occupations):
6 6 0	Agents (express companies)
	Express messengers and railway mail clerks
6 6 2	Express messengers
6 6 4	Railway mail clerks
6 6 6	Mail carriers
6 6 8	Telegraph and telephone linemen
6 7 0	Telegraph messengers
6 7 2	Telegraph operators
6 7 4	Telephone operators
	Other transportation pursuits:
	Foremen and overseers (n. o. s.[1])
6 7 6	Road and street building and repairing
6 7 7	Telegraph and telephone
6 7 8	Water transportation
6 7 9	Other transportation
	Inspectors
6 8 0	Steam railroad
6 8 1	Street railroad
6 8 2	Telegraph and telephone
6 8 3	Other transportation
	Laborers (n. o. s[1])
6 8 5	Express companies
6 8 6	Pipe-lines
6 8 7	Telegraph and telephone
6 8 8	Water transportation
6 8 9	Other transportation

[1] Not otherwise specified.

LIST OF OCCUPATIONS AND OCCUPATION GROUPS WITH THEIR SYMBOLS — Continued.

Symbol.	Occupation and Occupation Group
	TRANSPORTATION — Continued.
	Other transportation pursuits. — Continued.
	Proprietors, officials, and managers (n.o.s.[1])
6 9 0	Telegraph and telephone
6 9 1	Other transportation
	Other occupations (semiskilled)
6 9 3	Road and street building and repairing
6 9 4	Steam railroad
6 9 5	Street railroad
6 9 6	Telegraph and telephone
6 9 7	Water transportation
6 9 9	Other transportation
	TRADE.
	Bankers, brokers, and money lenders
7 0 0	Bankers and ban officials
7 0 1	Commercial brokers and commission men
7 0 2	Loan brokers and loan company officials
7 0 3	Pawnbrokers
7 0 4	Stockbrokers
7 0 5	Brokers not specified and promoters
7 0 7	Clerks in stores
7 0 8	Commercial travelers
7 0 9	Decorators, drapers, and window dressers
	Deliverymen
7 1 0	Bakeries and laundries
7 1 1	Stores
	Floorwalkers, foremen, and overseers
7 1 3	Floorwalkers and foremen in stores
7 1 4	Foremen (warehouses, stockyards, etc.)
7 1 6	Inspectors, gaugers, and samplers
	Insurance agents and officials
7 1 8	Insurance agents
7 1 9	Officials of insurance companies
	Laborers in coal and lumber yards, warehouses, etc.
7 2 0	Coal yards
7 2 1	Elevators
7 2 2	Lumberyards
7 2 3	Stockyards
7 2 4	Warehouses
7 2 6	Laborers, porters, and helpers in stores
7 2 8	Newsboys
	Proprietors, officials, and managers (n o. s.[1])
7 3 0	Employment office keepers
7 3 1	Proprietors, etc., elevators
7 3 2	Proprietors, etc , warehouses
7 3 3	Other proprietors, officials, and managers
7 3 5	Real estate agents and officials
	Retail dealers
7 3 7	Agricultural implements and wagons

[1] Not otherwise specified.

LIST OF OCCUPATIONS AND OCCUPATION GROUPS WITH THEIR SYMBOLS — Continued.

Symbol	Occupation and Occupation Group
	TRADE — Continued
	Retail dealers — Continued.
7 3 8	Art stores and artists' materials
7 3 9	Automobiles and accessories
7 4 0	Bicycles
7 4 1	Books
7 4 2	Boots and shoes
7 4 3	Butchers and meat dealers
7 4 4	Buyers and shippers of grain
7 4 5	Buyers and shippers of live stock
7 4 6	Buyers and shippers of other farm produce
7 4 7	Candy and confectionery
7 4 8	Cigars and tobacco
7 4 9	Carpets and rugs
7 5 0	Clothing and men's furnishings
7 5 1	Coal and wood
7 5 2	Coffee and tea
7 5 3	Crockery, glassware, and queensware
7 5 4	Curios, antiques, and novelties
7 5 5	Delicatessen stores
7 5 6	Department stores
7 5 7	Drugs and medicines, including druggists and pharmacists
7 5 8	Dry goods, fancy goods, and notions
7 5 9	Five and ten cent and variety stores
7 6 0	Florists (dealers)
7 6 1	Flour and feed
7 6 2	Fruit
7 6 3	Furniture
7 6 4	Furs
7 6 5	Gas fixtures and electrical supplies
7 6 6	General stores
7 6 7	Groceries
7 6 8	Hardware, stoves, and cutlery
7 6 9	Harness and saddlery
7 7 0	Hucksters and peddlers
7 7 1	Ice
7 7 2	Jewelry
7 7 3	Junk
7 7 4	Leather and hides
7 7 6	Lumber
7 7 7	Milk
7 7 8	Music and musical instruments
7 7 9	Newsdealers
7 8 0	Oil, paint, and wall paper
7 8 1	Opticians
7 8 2	Produce and provisions
7 8 3	Rags
7 8 4	Stationery
7 8 5	Other specified retail dealers
7 8 6	Not specified retail dealers
	Salesmen and saleswomen
7 8 8	Auctioneers
7 8 9	Demonstrators
7 9 0	Sales agent
7 9 1	Salesmen and saleswomen (stores)

LIST OF OCCUPATIONS AND OCCUPATION GROUPS WITH THEIR SYMBOLS — Continued.

Symbol	Occupation and Occupation Group.
	TRADE — Continued.
7 9 3	Undertakers
7 9 5	Wholesale dealers, importers and exporters
	Other pursuits (semiskilled)
7 9 6	Fruit graders and packers
7 9 7	Meat cutters
7 9 8	Packers, wholesale and retail trade
7 9 9	Other occupations
	PUBLIC SERVICE (NOT ELSEWHERE CLASSIFIED).
8 0 0	Firemen (fire department)
8 0 2	Guards, watchmen, and doorkeepers
	Laborers (public service)
8 0 4	Garbage men and scavengers
8 0 5	Other laborers
	Marshals, sheriffs, detectives, etc.
8 0 7	Detectives
8 0 9	Marshals and constables
8 1 0	Probation and truant officers
8 1 2	Sheriffs
	Officials and inspectors (city and county)
8 1 4	Officials and inspectors (city)
8 1 5	Officials and inspectors (county)
	Officials and inspectors (state and United States)
8 1 7	Officials and inspectors (state)
8 1 8	Postmasters
8 1 9	Other United States officials
8 2 0	Policemen
8 2 2	Soldiers, sailors, and marines
	Other pursuits
8 2 4	Life-savers
8 2 5	Lighthouse keepers
8 2 6	Other occupations
	PROFESSIONAL SERVICE.
	Actors and showmen
8 2 8	Actors
8 2 9	Showmen
8 3 0	Architects
8 3 2	Artists, sculptors, and teachers of art
	Authors, editors, and reporters
8 3 4	Authors
8 3 5	Editors and reporters
8 3 7	Chemists, assayers, and metallurgists
8 3 9	Clergymen
8 4 0	College presidents and professors
8 4 2	Dentists
	Designers, draftsmen, and inventors
8 4 4	Designers
8 4 6	Draftsmen
8 4 8	Inventors

LIST OF OCCUPATIONS AND OCCUPATION GROUPS WITH THEIR SYMBOLS — Continued.

Symbol	Occupation and Occupation Group.
	PROFESSIONAL SERVICE — Continued.
8 5 0	Lawyers, judges, and justices
8 5 2	Musicians and teachers of music
8 5 4	Osteopaths
8 5 6	Photographers
8 5 8	Physicians and surgeons
	Teachers
8 6 0	Teachers (athletics, dancing, etc.)
8 6 2	Teachers (school)
	Technical engineers
8 6 4	Civil engineers and surveyors
8 6 6	Electrical engineers
8 6 8	Mechanical engineers[1]
8 7 0	Mining Engineers
8 7 2	Trained nurses
8 7 4	Veterinary surgeons
	Other professional pursuits
8 7 6	Aeronauts
8 7 8	Librarians
8 8 0	Other occupations
	Semiprofessional pursuits
8 8 2	Abstractors, notaries, and justices of peace
8 8 3	Fortune tellers, hypnotists, spiritualists, etc.
8 8 4	Healers (except osteopaths and physicians and surgeons)
8 8 5	Keepers of charitable and penal institutions
8 8 6	Keepers of pleasure resorts, race tracks, etc.
8 8 7	Officials of lodges, societies, etc.
8 8 8	Religious, charity, and welfare workers
8 8 9	Theatrical owners, managers, and officials
8 9 0	Turfmen and sportsmen
8 9 1	Other occupations
	Attendants and helpers (professional service)
8 9 3	Dentists' assistants and apprentices
8 9 4	Librarians' assistants and attendants
8 9 5	Physicians' and surgeons' attendants
8 9 6	Stage hands and circus helpers
8 9 7	Theater ushers
8 9 9	Other attendants and helpers
	DOMESTIC AND PERSONAL SERVICE.
9 0 0	Barbers, hairdressers, and manicurists
	Billiard room, dance hall, skating rink, etc., keepers
9 0 2	Billiard and pool room keepers
9 0 4	Dance hall, skating rink, etc., keepers
9 0 6	Boarding and lodging house keepers
9 0 8	Bootblacks
9 1 0	Charwomen and cleaners
9 1 2	Elevator tenders
9 1 4	Hotel keepers and managers
9 1 6	Housekeepers and stewards
9 1 8	Janitors and sextons
9 2 0	Laborers (domestic and professional service)

[1] Includes, also, all technical engineers not elsewhere classified.

LIST OF OCCUPATIONS AND OCCUPATION GROUPS WITH THEIR SYMBOLS — Continued.

Symbol.	Occupation and Occupation Group.
	DOMESTIC AND PERSONAL SERVICE — Continued.
9 2 2	Launderers and laundresses (not in laundry)
	Laundry operatives
9 2 4	Foremen and overseers
9 2 6	Laborers
9 2 8	Other operatives
	Laundry owners, officials, and managers
9 3 0	Managers and officials
9 3 2	Owners and proprietors
	Midwives and nurses (not trained)
9 3 4	Midwives
9 3 6	Nurses (not trained)
	Porters (except in stores)
9 3 8	Porters, domestic and professional service
9 4 0	Porters, steam railroad
9 4 2	Other porters (except in stores)
9 4 4	Restaurant, café, and lunch room keepers
	Servants
9 4 6	Bell boys, chore boys, etc.
9 4 8	Butlers
9 5 0	Chambermaids
9 5 2	Coachmen and footmen
9 5 4	Cooks
9 5 6	Ladies' maids, valets, etc.
9 5 8	Nurse maids
9 6 0	Other servants
9 6 2	Waiters
	Other pursuits
9 6 4	Bartenders
9 6 6	Bathhouse keepers and attendants
9 6 8	Cemetery keepers
9 7 0	Cleaners and renovators (clothing, etc)
9 7 2	Hunters, trappers and guides
9 7 4	Saloon keepers
9 7 6	Umbrella menders and scissors grinders
9 7 8	Other occupations
	CLERICAL OCCUPATIONS.
	Agents, canvassers, and collectors
9 8 0	Agents
9 8 2	Canvassers
9 8 4	Collectors
	Bookkeepers, cashiers, and accountants
9 8 6	Accountants and auditors
9 8 8	Bookkeepers and cashiers
	Clerks (except clerks in stores).
9 9 0	Shipping clerks
9 9 2	Weighers
9 9 4	Other clerks
	Messenger, bundle, and office boys and girls[1]
9 9 6	Bundle and cash boys and girls
9 9 7	Messenger, errand, and office boys and girls
9 9 9	Stenographers and typists

[1] Except telegraph messengers.

INDUSTRY INDEX

This industry index includes most of the manufacturing and a few other industries. Each industry is preceded by its "laborer (n. o s [1])" symbol and is followed by its "semi-skilled operative (n o. s.[1])" symbol This index should be referred to only when the occupation to be classified is plainly a "laborer" or a "semiskilled" occupation and is not included in the alphabetical index

For the purposes of this classification, those occupations are considered "semiskilled" for the pursuance of which only a short period or no period of preliminary training is necessary, and which in their pursuance call for only a moderate degree of judgment or of manual dexterity. "Laborers" are considered to include those occupations the workers in which require no special training, judgment, or manual dexterity, but supply mainly muscular strength for the performance of coarse, heavy work.

Laborer[1] symbol	INDUSTRY	Semi-skilled [1] symbol.
2 4 4	Abattoir	4 6 2
2 0 6	Acids	4 2 4
2 6 6	Adding machines	4 8 2
3 5 6	Advertising novelties	5 7 4
2 6 6	Aeroplanes and parts	4 8 2
2 8 2	Agateware	4 9 8
2 5 4	Agricultural implements	4 7 0
3 4 2	Alcohol	5 6 0
2 0 6	Alum	4 2 4
2 8 2	Aluminum ware	4 9 8
2 0 2	Ammunition	4 2 0
2 6 6	Apiarists' supplies	4 8 2
3 3 6	Arc and incandescent lamps	5 5 4
3 5 6	Artificial flowers	5 7 4
3 5 6	Artificial limbs.	5 7 4
2 1 4	Artificial stone	4 3 2
3 5 6	Artists' materials	5 7 4
3 5 6	Asbestos products	5 7 4
2 1 4	Asphalt works	4 3 2
2 6 6	Augers and bits	4 8 2
2 5 6	Automobile bodies and parts	4 7 2
2 6 6	Automobile repair shop	4 8 2
2 6 6	Automobile service station	4 8 2
2 5 6	Automobiles	4 7 2
2 6 6	Axes and hatchets	4 8 2
2 0 6	Axle grease	4 2 4
2 8 4	Babbitt metal	5 0 0
3 2 6	Bags, except paper	5 4 2
2 3 2	Bakery	4 5 0
2 0 6	Baking powder	4 2 4
2 5 8	Bar, beam, or bloom mill	4 7 4
2 6 6	Barbed wire	4 8 2
2 9 2	Baskets	5 0 8
3 3 6	Batteries	5 5 4
3 5 6	Beadwork	5 7 4
2 7 0	Bells	4 8 6
3 4 8	Belting (except leather)	5 6 6
2 6 6	Bicycles	4 8 2
2 8 6	Billiard tables and materials	5 0 2
2 0 6	Blacking, stains, and dressings	4 2 4
2 9 6	Blank books	5 1 2
2 5 8	Blast furnace	4 7 4
3 1 4	Bleachery (textile)	5 3 0
2 0 6	Blue vitriol	4 2 4

[1] Not otherwise specified.

Laborer symbol	INDUSTRY.	Semi-skilled symbol.
2 0 6	Bluing	4 2 4
2 6 6	Boiler shop	4 8 2
2 6 6	Bolts, nuts, washers, and rivets	4 8 2
2 0 6	Bone black	4 2 4
2 9 8	Bookbinding	5 1 4
3 0 0	Boot and shoe cut stock	5 1 6
3 0 0	Boot and shoe findings	5 1 6
3 0 0	Boots and shoes (leather)	5 1 6
3 4 8	Boots and shoes (rubber)	5 6 6
2 1 2	Bottle factory	4 3 0
3 4 2	Bottling works (n. o s)	5 6 0
2 9 0	Boxes (cigar)	5 0 6
3 4 4	Boxes (paper)	5 6 2
2 9 0	Boxes (wood)	5 0 6
2 7 0	Brass factory or foundry	4 8 6
3 4 2	Brewery	5 6 0
2 1 0	Brick factory or yard	4 2 8
2 6 6	Bridge works	4 8 2
2 8 4	Britannia factory	5 0 0
3 2 8	Brooms and brushes	5 4 4
2 6 6	Buckles (iron)	4 8 2
1 9 6	Building and hand trades	5 4 6
2 3 4	Butter, or butter reworking	4 5 2
3 3 0	Buttons	5 4 8
3 5 6	Cameras and kodaks	5 7 4
2 8 2	Can factory	4 9 8
2 0 6	Candles	4 2 4
2 3 6	Candy	4 5 4
2 4 2	Cannery (fruit and vegetable)	4 6 0
2 6 0	Car or railroad shops	4 7 6
2 0 6	Carbon black	4 2 4
3 5 6	Carbon paper	5 7 4
2 9 6	Card cutting and designing	5 1 2
2 9 6	Cardboard	5 1 2
3 0 4	Carpet mill	5 2 0
3 0 4	Carpets, rag	5 2 0
2 6 4	Carriage and wagon materials	4 8 0
2 6 4	Carriages and sleds, children's	4 8 0
2 6 4	Carriages and wagons	4 8 0
2 0 2	Cartridges	4 2 0
2 6 6	Cash registers	4 8 2
2 6 6	Cast-iron pipe	4 8 2
2 6 6	Castings (iron)	4 8 2
3 5 6	Celluloid novelties	5 7 4
2 1 4	Cement and gypsum	4 3 2
2 4 8	Cereals and breakfast foods	4 6 6
2 8 6	Chair factory	5 0 2
3 3 2	Charcoal and coke	5 5 0
2 3 4	Cheese	4 5 2
2 0 6	Chemicals	4 2 4
2 3 6	Chewing gum	4 5 4
2 1 8	China decorating	4 3 6
2 1 8	Chinaware	4 3 6
2 6 6	Chisels and planes	4 8 2
2 4 8	Chocolate and cocoa	4 6 6
2 4 8	Cider	4 6 6
2 0 8	Cigars and cigarettes	4 2 6
2 0 6	Cleansing preparations	4 2 4
2 7 2	Clock and watch materials	4 8 8
2 7 2	Clocks and watches	4 8 8
3 1 4	Cloth sponging and refinishing	5 3 0
2 3 0	Clothing (except suits, coats, cloaks and overalls)	4 4 8

Laborer symbol.	INDUSTRY.	Semi-skilled symbol.
2 2 8	Clothing (suits, coats, cloaks, and overalls)	4 4 6
2 4 8	Coffee roasting and grinding	4 6 6
2 8 6	Coffins and burial cases	5 0 2
2 2 6	Collars and cuffs	4 4 4
3 5 8	Combs and hairpins (except metal and rubber)	5 7 6
3 5 6	Comforts and quilts	5 7 4
2 3 4	Condensed milk	4 5 2
2 3 6	Confectionery	4 5 4
2 9 2	Cooperage	5 0 8
2 7 4	Copper factory or refining	4 9 0
2 7 4	Copper smelter	4 9 0
2 0 6	Copperas	4 2 4
2 4 8	Cordials and flavoring sirups	4 6 6
2 9 2	Cork cutting	5 0 8
2 2 0	Corsets	4 3 8
3 5 6	Cotton batting	5 7 4
3 5 6	Cotton gin	5 7 4
3 0 6	Cotton mill	5 2 2
3 5 6	Cottonseed oil and cake	5 7 4
2 3 2	Crackers	4 5 0
2 9 0	Crates	5 0 6
2 0 6	Cream of tartar	4 2 4
2 6 6	Cream separators	4 8 2
2 3 4	Creamery	4 5 2
2 1 8	Crucibles	4 3 6
2 6 6	Cutlery and edge tools	4 8 2
2 6 6	Dairymen's supplies	4 8 2
3 5 6	Dental goods	5 7 4
2 8 6	Desk factory	5 0 2
2 6 6	Doors and shutters (iron)	4 8 2
2 9 0	Doors and shutters (wood)	5 0 6
3 1 0	Dress and cloak trimmings, braids, etc.	5 2 6
2 0 6	Drug grinding	4 2 4
2 0 6	Druggists' preparations	4 2 4
2 0 0	Dryers (paint)	4 1 8
3 1 4	Dyehouse	5 3 0
2 0 6	Dyestuffs and extracts	4 2 4
2 0 2	Dynamite	4 2 0
3 3 6	Dynamos	5 5 4
2 1 8	Earthen and stone ware	4 3 6
3 3 6	Electric heating apparatus	5 5 4
3 3 4	Electric light or power plant	5 5 2
3 3 6	Electric lighting fixtures	5 5 4
3 3 6	Electrical machinery, apparatus, and supplies	5 5 4
2 8 4	Electroplating (n. o s.)	5 0 0
2 6 6	Elevators (passenger and freight)	4 8 2
3 1 0	Embroideries	5 2 6
3 5 6	Emery and other abrasive wheels	5 7 4
2 6 6	Enameling (n. o. s)	4 8 2
2 6 6	Engines, steam, water, and gas	4 8 2
3 5 6	Engravers' materials	5 7 4
2 9 8	Engraving and diesinking (n. o. s.)	5 1 4
2 9 8	Engraving, steel and copper plate	5 1 4
2 9 8	Engraving (wood)	5 1 4
2 9 6	Envelopes	5 1 2
2 9 2	Excelsior mill	5 0 8
2 0 2	Explosives	4 2 0
6 8 5	Express company (any).	6 9 9
3 5 6	Fancy articles (n. o. s.)	5 7 4
3 5 6	Feather pillows and beds	5 7 4
3 5 6	Feathers and plumes.	5 7 4
2 4 0	Feed mill,	4 5 8
3 1 6	Felt, or felt mill.	5 3 2

Laborer symbol	INDUSTRY	Semi-skilled symbol.
198	Fertilizer factory	416
266	Files	482
200	Fillers (used in painting)	418
266	Fire escapes	482
266	Fire extinguishers.	482
266	Firearms	482
266	Fireless cookers	482
202	Fireworks	420
238	Fish curing and packing	456
326	Flags and banners	542
248	Flavoring extracts	466
320	Flax mill	536
240	Flour or grain mill	458
270	Foundry (brass)	486
266	Foundry (iron)	482
268	Foundry (n o s)	484
356	Foundry supplies	574
242	Fruit and vegetable canning	460
242	Fruit drying	460
356	Fuel, manufactured	574
356	Fur goods	574
230	Furnishing goods (men's)	448
286	Furniture	502
356	Furs, dressed	574
202	Fuse	420
266	Galvanizing	482
284	Gas fixtures	500
266	Gas machines	482
266	Gas meters and water meters	482
338	Gas works	556
206	Gases (except illuminating and heating)	424
212	Glass	430
212	Glass cutting, staining, and ornamenting	430
222	Gloves (leather)	440
246	Glucose	464
206	Glue	424
206	Glycerin	424
276	Gold or silver factory	492
276	Gold or silver leaf and foil	492
721	Grain elevator	799
356	Graphite, ground and refined	574
206	Greases	424
356	Grindstones	574
240	Gristmill	458
198	Guano works	416
266	Guns and pistols	482
356	Hair work	574
326	Haircloth	542
322	Hammocks	538
348	Hand stamps	566
230	Handkerchiefs	448
266	Hardware	482
250	Harness and saddles	468
254	Harvesting machinery	470
356	Hat and cap materials	574
230	Hats and caps (except felt, straw, and wool)	448
350	Hats, straw	568
224	Hats (wool or felt)	442
318	Hemp or jute mill	534
292	Hogsheads and barrels	508
356	Hones and whetstones	574
348	Hose, rubber or woven	564
308	Hosiery mill	526

Laborer symbol	INDUSTRY.	Semi-skilled symbol.
2 6 6	Hot air furnaces	4 8 2
3 2 6	Horse blankets, carriage robes, etc.	5 4 2
3 5 6	House furnishing goods (n. o. s.)	5 7 4
2 4 8	Ice cream	4 6 6
3 5 6	Ice, manufactured	5 7 4
2 5 4	Implement factory	4 7 0
2 6 6	Incubators and brooders	4 8 2
2 0 6	Ink	4 2 4
3 5 6	Instrument cases	5 7 4
3 5 6	Instruments, professional and scientific	5 7 4
2 5 8	Iron furnace	4 7 4
3 5 6	Ivory, shell, or bone work	5 7 4
2 6 6	Japanning (n o. s)	4 8 2
2 0 0	Japans	4 1 8
2 7 8	Jewelry	4 9 4
2 9 8	Job printing	5 1 4
3 0 8	Knitting mill	5 2 4
2 9 6	Labels and tags	5 1 2
3 1 0	Lace or embroidery mill	5 2 6
2 0 0	Lacquers	4 1 8
2 0 6	Lampblack	4 2 4
2 8 4	Lamps and lanterns	5 0 0
2 7 8	Lapidary work	4 9 4
2 4 4	Lard	4 6 2
2 9 2	Lasts	5 0 8
2 9 0	Lath mill	5 0 6
9 2 6	Laundries	9 2 8
2 8 0	Lead — bar, pipe, and sheet	4 9 6
2 8 0	Lead factory	4 9 6
2 8 0	Lead smelting and refining	4 9 6
3 4 0	Leather belts	5 5 8
3 4 0	Leather cases and pocketbooks	5 5 8
3 4 0	Leather goods (n o. s.)	5 5 8
2 6 6	Lightning rods	4 8 2
2 1 4	Lime	4 3 2
3 2 0	Linen mill	5 3 6
3 5 6	Linseed oil	5 7 4
2 9 8	Lithographing	5 1 4
2 6 6	Locks, hinges, etc	4 8 2
2 6 6	Locomotives	4 8 2
2 9 2	Looking-glass and picture frames	5 0 8
2 0 6	Lye	4 2 4
2 4 8	Macaroni	4 6 6
2 6 6	Machine shop	4 8 2
2 6 6	Machinery (all used in manufacturing)	4 8 2
3 4 2	Malt	5 6 0
2 1 6	Marble or stone yard	4 3 4
2 6 2	Masts, spars, oars, and rigging	4 7 8
2 9 2	Matches	5 0 8
3 2 6	Mats and matting (from cocoa fiber or grass)	5 4 2
3 5 6	Mattresses	5 7 4
2 4 4	Meat canning	4 6 2
3 5 6	Metal novelties	5 7 4
3 5 6	Mica factory	5 7 4
3 5 6	Microscopes, opera glasses, etc.	5 7 4
2 3 4	Milk products	4 5 2
3 4 2	Mineral and soda water	5 6 0
3 5 6	Minerals and earths, ground	5 7 4
3 5 6	Mirrors and looking-glasses	5 7 4
3 5 6	Models and patterns (except paper patterns)	5 7 4
2 4 8	Molasses	4 6 6
2 1 6	Monuments and tombstones	3 4 4
3 5 6	Mops and dusters	5 7 4
3 0 2	Morocco factory	5 1 8
3 0 6	Mosquito netting	5 2 2

Laborer symbol.	INDUSTRY.	Semi-skilled symbol.
2 6 6	Poultrymen's supplies	4 8 2
2 0 2	Powder	4 2 0
2 4 8	Prepared food for animals and fowls	4 6 6
3 1 4	Print works	5 3 0
2 9 8	Printing and publishing	5 1 4
3 5 6	Printing materials (n. o. s.)	5 7 4
2 9 8	Publishing house	5 1 4
2 9 2	Pulp goods	5 0 8
2 6 6	Pumps	4 8 2
3 5 6	Quilt mill	5 7 4
2 6 6	Radiators and heating boilers	4 8 2
2 5 8	Rail mill	4 7 4
2 6 0	Railroad repair shop	4 7 6
2 9 2	Rattan and willow ware	5 0 8
2 6 6	Razors	4 8 2
3 5 6	Records, phonograph and graphophone	5 7 4
2 8 6	Refrigerators	5 0 2
3 2 6	Regalia, badges, and emblems	5 4 2
2 4 8	Rice cleaning and polishing	4 6 6
2 5 8	Rod mill (iron)	4 7 4
3 5 6	Roofing materials	5 7 4
3 2 2	Rope or cordage factory	5 3 8
3 5 4	Rosin	5 7 2
3 4 8	Rubber belts	5 6 6
3 4 8	Rubber goods.	5 6 6
3 4 8	Rubber hose	5 6 6
3 4 8	Rubber tires	5 6 6
3 0 4	Rugs	5 2 0
2 9 2	Rules, ivory and wood	5 0 8
2 6 6	Safes and vaults	4 8 2
3 2 4	Sails, awnings, or tents	5 4 0
2 0 6	Salts (chemical)	4 2 4
3 5 6	Sand and emery paper and cloth	5 7 4
2 3 8	Sardine factory.	4 5 6
2 9 0	Sashes and doors	5 0 6
3 4 0	Satchels and valises	5 5 8
2 4 4	Sausage	4 6 2
2 9 0	Sawmill	5 0 6
2 6 6	Saws	4 8 2
2 6 6	Scales and balances	4 8 2
2 6 6	Scissors, shears, and clippers	4 8 2
2 6 6	Screen wire	4 8 2
2 6 6	Screws	4 8 2
2 5 4	Seeders, planters, and drills	4 7 0
2 1 0	Sewer pipe	4 2 8
2 9 2	Sewing machine cases	5 0 8
2 6 6	Sewing machines	4 8 2
2 0 0	Shellac	4 1 8
2 9 0	Shingle mill	5 0 6
2 6 2	Ship and boat building	4 7 8
2 3 0	Shirt waists	4 4 8
2 2 6	Shirts	4 4 4
3 1 6	Shoddy.	5 3 2
2 9 2	Shooks mill (barrel)	5 0 8
2 9 0	Shooks mill (box)	5 0 6
2 6 6	Shovels, spades, and hoes	4 8 2
2 8 6	Show cases	5 0 2
2 9 2	Shuttles	5 0 8
3 5 6	Signs	5 7 4
3 1 2	Silk mill	5 2 8
2 7 6	Silversmithing and silverware	4 9 2
2 4 8	Sirup	4 6 6
2 3 4	Skimming station	4 5 2
2 9 2	Slat factory	5 0 8
2 1 6	Slate (except quarrying)	4 3 4

Laborer symbol.	INDUSTRY.	Semi-skilled symbol.
2 4 4	Slaughtering and meat packing	4 6 2
2 0 8	Snuff	4 2 6
2 0 4	Soap	4 2 2
2 0 6	Soda	4 2 4
2 6 6	Soda-water apparatus	4 8 2
2 8 4	Solder	5 0 0
2 0 6	Solvay works	4 2 4
2 4 8	Spice roasting and grinding	4 6 6
3 5 6	Sporting and athletic goods	5 7 4
2 0 2	Squib factory	4 2 0
2 8 2	Stamped and enameled ware	4 9 8
2 0 6	Starch	4 2 4
3 5 6	Stationery goods (n. o. s.)	5 7 4
2 1 8	Statuary and earthen art goods	4 3 6
2 9 2	Staves	5 0 8
2 6 6	Steam and hot water heating apparatus	4 8 2
2 6 0	Steam or street railroad cars	4 7 6
2 6 6	Steam fittings	4 8 2
3 5 6	Steam packing	5 7 4
6 4 0	Steam railroad	6 9 4
2 6 6	Steam shovels	4 8 2
2 5 8	Steel bars and rods	4 7 4
2 5 8	Steel plates and sheets	4 7 4
2 5 8	Steel rails	4 7 4
2 5 8	Steel rolling mill	4 7 4
2 5 8	Steel works	4 7 4
3 5 6	Stencils and brands	5 7 4
3 5 6	Stereopticons and stereoscopes	5 7 4
2 9 8	Stereotyping and electrotyping	5 1 4
3 0 8	Stockinet factory	5 2 4
7 2 3	Stockyards	7 9 9
2 1 4	Stone crushing	4 3 2
2 8 6	Store and office fixtures	5 0 2
2 0 6	Stove polish	4 2 4
2 6 6	Stoves and ranges	4 8 2
2 6 6	Stoves, gas and oil	4 8 2
2 9 4	Strawboard factory	5 1 0
6 4 2	Street railroad	6 9 5
2 6 6	Structural iron work (not made in steel mills)	4 8 2
2 5 8	Structural steel.	4 7 4
2 1 4	Stucco works	4 3 2
2 4 6	Sugar factory or refinery	4 6 4
2 9 4	Sulphite mill	5 1 0
2 0 6	Sulphur	4 2 4
3 5 6	Surgical appliances	5 7 4
2 3 0	Suspenders, garters, and elastic woven goods	4 4 8
3 3 6	Switchboards	5 5 4
2 6 6	Table cutlery (except silver and plated ware)	4 8 2
2 8 6	Table factory	5 0 2
2 6 6	Tacks	4 8 2
2 2 8	Tailor shop	4 4 6
2 0 6	Tallow	4 2 4
2 6 6	Tanks (iron and steel)	4 8 2
3 0 2	Tannery	5 1 8
3 0 6	Tape and webbing (cotton)	5 2 2
2 0 6	Tar	4 2 4
3 3 6	Telegraph and telephone apparatus	5 5 4
6 8 7	Telegraph or telephone	6 9 6
2 5 8	Terneplate	4 7 4
3 1 4	Textile dyeing	5 3 0
3 1 4	Textile finishing or printing	5 3 0
3 5 6	Theatrical scenery	5 7 4
3 0 6	Thread, cotton	5 2 2
2 5 4	Threshing machinery	4 7 0
2 9 0	Tie plant	5 0 6

Laborer symbol	INDUSTRY.	Semi-skilled symbol
2 1 0	Tile or terra-cotta	4 2 8
2 8 2	Tin, and sheet iron work	4 9 8
2 8 4	Tin foil	5 0 0
2 5 8	Tin plate and terneplate	4 7 4
2 8 2	Tinware and enamel ware	4 9 8
2 0 8	Tobacco factory	4 2 6
2 0 6	Toilet preparations	4 2 4
2 6 6	Tools and cutlery	4 8 2
2 0 2	Torpedoes	4 2 0
3 5 6	Toys and games	5 7 4
3 3 6	Transformers (electric)	5 5 4
3 5 2	Trunks	5 7 0
3 5 4	Turpentine distillery	5 7 2
3 2 2	Twine	5 3 8
2 8 0	Type founding	4 9 6
3 5 6	Typewriter ribbons	5 7 4
2 6 6	Typewriters	4 8 2
3 5 6	Umbrellas and canes	5 7 4
2 3 0	Underwear (except knitted)	4 4 8
3 2 6	Upholstering materials	5 4 2
2 6 6	Vacuum cleaners	4 8 2
2 6 6	Vault lights and ventilators	4 8 2
3 1 2	Velvet factory	5 2 8
2 9 2	Veneer works	5 0 8
2 6 6	Ventilating fans	4 8 2
2 4 8	Vinegar	4 6 6
2 9 6	Wall paper	5 1 2
2 1 4	Wall plaster	4 3 2
7 2 4	Warehouses and cold storage plants	7 9 9
2 6 6	Washing machines and clothes wringers	4 8 2
3 2 6	Waste	5 4 2
2 7 2	Watchcases	4 8 8
2 9 0	Weather strips (wood)	5 0 6
2 6 6	Wheelbarrows	4 8 2
3 5 6	Whips	5 7 4
3 4 2	Whisky or rum	5 6 0
2 0 0	White lead	4 1 8
2 8 4	White metal	5 0 0
2 6 6	Windmills	4 8 2
2 9 0	Window and door screens	5 0 6
3 5 6	Window shades and fixtures	5 7 4
3 4 2	Winery	5 6 0
2 7 0	Wire (brass)	4 8 6
2 5 8	Wire mill	4 7 4
2 5 8	Wire (n o s)	4 7 4
2 6 6	Wire rope and cable	4 8 2
2 6 6	Wirework	4 8 2
2 0 6	Wood alcohol	4 2 4
2 9 2	Wood carpet	5 0 8
2 0 6	Wood distillation	4 2 4
3 5 6	Wood novelties	5 7 4
2 9 2	Wood preserving	5 0 8
2 9 2	Wooden goods (n. o s)	5 0 8
2 9 2	Wood-turning shop	5 0 8
3 1 6	Wool pulling	5 3 2
3 1 6	Wool scouring	5 3 2
3 1 6	Woolen or worsted mill	5 3 2
2 6 6	Woven wire fencing	4 8 2
2 3 0	Wrappers and dresses	4 4 8
3 0 6	Yarn (cotton)	5 2 2
3 2 6	Yarn (n o s)	5 4 2
3 1 6	Yarn (woolen)	5 3 2
2 0 6	Yeast	4 2 4
2 8 0	Zinc factory	4 9 6
2 8 0	Zinc smelter or refinery	4 9 6

Nosology not an exact science. — The following reported causes of death will enable the student to decide whether or not nosology is an exact science:

"Went to bed feeling well, but woke up dead."

"Died suddenly at the age of 103. To this time he bid fair to reach a ripe old age."

"Deceased had never been fatally sick."

"Last illness caused by chronic rheumatism, but was cured before death."

"Died suddenly, nothing serious."

"While cranking his automobile sustained what is technically known as a colles fracture of the right rib"

"Kick by horse showed on left kidney."

"Chronic disease."

"Deceased died from blood poison caused by a broken ankle, which is remarkable, as the automobile struck him between the lamp and the radiator."

"Death caused by five doctors."

"Delicate from birth."

"Artery lung busted."

"Collocinphantum."

"Typhoid fever, bronchitis, pneumonia and a miscarriage."
— "Vital Statistics."

EXERCISES AND QUESTIONS

1. What does Van Buren mean by the "Will-o'-the-wisp" of the statistics of causes of death? [See Am. J. P. H., Dec. 1917, p. 1016.]

2. What changes have taken place in the nomenclature of "Tuberculosis," during the last century?

3. Give ten examples of joint causes of death, indicating in each case which is primary and which secondary.

4. What preparations are being made to revise the present International List of Causes of Death?

5. Select the appropriate cause of death for statistical report from the following joint causes of death, and give reason for your selection.

a. Broncho-pneumonia and measles.
b. Infantile diarrhœa and convulsions.
c. Scarlet fever and diphtheria.
d. Nephritis and scarlet fever.
e. Pulmonary tuberculosis and puerperal septicemia.
f. Typhoid fever and pneumonia.
g. Pericarditis and appendicitis.
h. Cirrhosis and angina pectoris.
i. Saturnism and peritonitis.
j. Old age and bronchitis.

CHAPTER X

ANALYSIS OF DEATH-RATES

Reasons for Analyzing a Death-rate. — We have now covered the principal methods used in the simpler forms of statistical study. We have seen the futility of using general death-rates for comparing the mortality of different places. We have learned how to compute specific rates for groups and classes, particular rates for different diseases and special rates of various kinds. Let us now put these ideas together and say that *the way to use a general death-rate is to analyze it.* Taken by itself it means very little, but if properly analyzed it will yield us useful information.

Two Methods of Analysis. — There are two methods of analyzing a general death-rate.

One is to sub-divide the numerator of the fraction into classes and groups, leaving the denominator of the fraction unchanged. The total population at mid-year is taken as the denominator of the fraction. This is sometimes done in separating all of the deaths in a year according to months and dividing each by the total population. It has the advantage that the sum of all the parts is equal to the whole. In the case mentioned the sum of all the monthly rates gives the yearly rate. It has the disadvantage that the figures cannot be compared or any standard easily carried in the mind.

Another and better method is to sub-divide both the numerator and denominator into classes and groups, that is, to find their specific rates. Here the sum of the rates resulting from the separation does not equal the whole. The weighted average of the constituent rates will, however, equal the whole.

Let us take a simple example:

In 1910 in Massachusetts there were the following populations and deaths classified by sex.

TABLE 81

POPULATION AND DEATHS: MASSACHUSETTS

	Population	Deaths
(1)	(2)	(3)
Males .	1,655,248	28,259
Females. . .	1,711,168	26,148
Total .. .	3,366,416	54,407

According to the first method of analysis the partial rates would be 28,259 ÷ 3366 = 8.4 for males, and 26,148 ÷ 3366 = 7.7 for females, the sum being 16.1, which is the same as dividing 54,407 by 3366, *i.e.*, 16.1 per 1000.

According to the second method the specific rate for males is 28,259 ÷ 1655 = 17.1, and for females, 26,148 ÷ 1711 = 15.3. In this case the weighted average would be (17.1 × 1655 + 15.3 × 1711) ÷ 3366 = 16.1 per 1000. The advantage of this second method is obvious, as one may readily compare the rate of 17.1 for males, and that of 15.3 for females, with 16.1, the death-rate for the entire population. In other words, this method of analysis gives us a chance to compare, and that is a prime object of statistical study.

Useful subdivisions. — For the purpose of analyzing a general death-rate we may subdivide the area geographically, finding the specific death-rate for each part. A state may be subdivided into counties, boroughs, cities and towns; or into urban and rural districts. A large city may be divided into wards, precincts or blocks. The subdivisions must be so chosen that both the population and the deaths may be obtained for each one. This often limits the comparison to political subdivisions. Those who take the census and those who keep the death records should get together and see that the geographical subdivisions correspond. Having made these subdivisions and obtained the rates for each, the results should be arrayed and studied by the statistical method described in a later chapter.

We may subdivide the year into seasons, months, weeks, or even days and ascertain the specific death-rate for each subdivision. These results should be arranged for chronological study, and for comparing the results for similar seasons or months for different years.

We may subdivide the population by sex, by nationality, by occupation, and in all sorts of ways.

We may subdivide the deaths according to cause, using either individual causes or classes of causes.

And finally we may use these various separations in combination with each other.

Example of the analysis of a general death-rate for a state. — To give a complete example of an analysis of the general death-rate of a state would require a small volume. A few hints may be given by asking a number of questions in regard to Massachusetts for the year 1910.

According to the 73d Registration Report the general death-rate for the state was 16.1.

Q. Was the death-rate uniform throughout the state?

The answer is obtained by finding the rate for each county and placing them in array, that is, in order of magnitude. The result is as follows:

TABLE 82

DEATH-RATES BY COUNTIES: MASSACHUSETTS, 1910

County.	General death-rate.	County.	General death-rate.
(1)	(2)	(1)	(2)
Norfolk . .	13 3	Essex.	15.9
Plymouth. . .	14 2	Bristol	16 3
Middlesex. . . .	15 4	Hampden.	16 8
Franklin.	15 5	Suffolk.	17.0
Worcester . . .	15 6	Barnstable.	18 1
Berkshire	15 6	Dukes	19 1
Hampshire. .	15 7	Nantucket.	20 2

Q. What was the *median* death-rate for the different counties, that is, the rate for the county in the middle of the list?

It was 15.8, *i.e.*, between 15.7 and 15.9.

Q. Why is this median rate lower than 16.1, the rate for the entire state?

The more populous counties have death-rates relatively high and this brings up the average. An average of these county rates weighted according to their population would give 16.1.

Q. Why was the rate for Nantucket county so much higher than that for Norfolk?

In order to answer this question intelligently we need to find out *when* the deaths occurred (seasonal distribution), *where* the deaths occurred (geographical distribution), *who* died (distribution by sex, age, nationality), *what* was the cause of death. Knowing these facts we should then seek to correlate them with controllable conditions.

As a rule a county is not a good geographical unit for such a study as it is difficult to get the facts. A city is better.

Comparison of the death-rates of two cities. — In 1910 the general death-rates of the cities of Massachusetts which had populations exceeding 50,000 were as follows:

TABLE 83

DEATH-RATES OF CERTAIN CITIES IN MASSACHUSETTS
1910

City.	General death-rate.	City	General death-rate
(1)	(2)	(1)	(2)
Brockton	12 3	Boston	17.2
Lynn	13 1	Holyoke	17.7
Somerville	13 4	Lawrence	17 7
Cambridge	15 0	Fall River	18.4
Springfield	16 6	New Bedford	18 6
Worcester	16 9	Lowell	19.7

Q. Why was the death-rate so much higher in Lowell than in Brockton?

We naturally look first to differences in age and sex distribution. The U. S. Census gives us the following information:

TABLE 84

AGE AND SEX DISTRIBUTION OF POPULATION IN BROCKTON AND LOWELL, MASS.

	Brockton.	Lowell.
(1)	(2)	(3)
Per cent of population under 10 years		
Male	8 8	9.3
Female	8.6	9 3
Per cent of population over 45 years		
Male	10.1	9.2
Female	10.6	10.8

These differences are not striking, except that Lowell has a somewhat larger percentage of children under ten years of age. How about infants? There is not much difference. In Brockton the infant population was 2.15 per cent of the total, in Lowell, 2.19 per cent. The sex differences are not great except that in Lowell in the age-group 15–44 years there are more females than males, while in Brockton the numbers are about alike.

Let us next turn to nationality. Here we find a great difference. In Brockton, 72 per cent of the population were native white and 27 per cent foreign-born white, but in Lowell only 59 per cent were native white while 40 per cent were foreign-born white. Pursuing this further we find that in Lowell the foreign-born whites were made up of French Canadians, 28.3 per cent; Irish, 23.0 per cent; English, 10.5 per cent; Canadians other than French, 9.3 per cent; Greeks, 8.7 per cent. The corresponding figures for Brockton are not given in the census report.

With these fundamental differences in mind we must next turn to industrial conditions, living conditions, etc. Brockton is a shoe city, Lowell a textile city. The housing conditions of the working classes in Brockton are better than in Lowell. These matters should be studied in detail.

But what of the causes of death? The annual report of the State Board of Health shows that the death-rate for pneumonia was 118 per 100,000 in Brockton, but 210 in Lowell; tuberculosis 88 and 137 respectively, diarrhea and cholera morbus 23 and 184. This last is a very important difference.

Turning to the age distribution of deaths we find that in Brockton 18.5 per cent of the deaths were infants, in Lowell 25.2 per cent. Evidently the large number of infant deaths, the large numbers of deaths from dysentery and the large foreign population in Lowell point to certain environmental conditions which influence mortality.

In order to get these facts it was necessary to consult the State Registration Report, the Annual Report of the State Board of Health and the Census Report. The annual reports of the local boards of health should have contained these essential data; in fact they should have contained the following specific death-rates for 1910:

TABLE 85

SPECIFIC DEATH-RATES BY AGE-GROUPS FOR BROCKTON AND LOWELL: 1910

Age-group.	Specific death-rates per 1000			
	Brockton		Lowell.	
	Male	Female	Male	Female
(1)	(2)	(3)	(4)	(5)
0–1	123 0	101 0	286 0	237 0
1–4	8 0	13.0	31 0	35 0
5–9	3 5	6 5	5 2	4 6
10–14	2 1	3 0	1 6	2.7
15–19	4 0	3 2	4 7	3 1
20–24	3 1	2 6	5 2	5 0
25–34	3 9	6 0	7 5	6 8
35–44	4 7	4 3	9 8	10 7
45–64	18 4	11 8	24 0	23.0
65–	106 0	90 0	99 0	95 0

These figures show directly that the infant death-rate was much higher in Lowell than in Brockton, that the death-rate for young children was also higher. This would point at once to home environment. But the rates were also higher in Lowell for the middle-age groups, which would point to greater industrial hazards there.

"Rates" not the only method of comparison. — So much has been said about rates and specific rates that there is danger that the student may come to think of them as the only method of statistical comparison. That is far from being the case.

The seasonal changes in mortality may be shown in three ways, each of which has its use. In Massachusetts the general death-rate for 1910 was 16.1 per 1000. It varied seasonally as follows:

TABLE 86

SEASONAL DISTRIBUTION OF MORTALITY

Massachusetts, 1910

Month.	Death-rate.	Percentage of total deaths	Ratio of monthly deaths to average number for each month.
(1)	(2)	(3)	(4)
January	17.1	8.9	106
February	17.1	8.1	106
March	17 8	9.5	110
April	17 2	8 8	107
May	15.2	8 0	94
June	14 4	7.3	89
July	17.2	9 0	107
August	16.6	8 7	103
September	15 8	8.0	98
October	14 7	7.7	91
November	14.8	7.5	92
December	16.2	8.5	101
Year	16.1	100.0	100

Column (2) gives the death-rate for each month as compared with the yearly rate. Columns (3) and (4) are most useful in comparing one year with another. They do not involve population, an uncertain factor in all but the census years, but on the other hand a change in one month affects the figures in all the other months.

EXERCISES AND QUESTIONS

1. Make a statistical analysis of the general death-rates of Boston and Baltimore for the year 1910.

2. Make a statistical analysis of the general death-rates of Chicago and New Orleans for the year 1910.

3. Make a statistical analysis of the general death-rates of other cities to be assigned by instructor.

4. Find the median death-rate for the counties of New York state for 1910.

5. Compare the seasonal mortalities of San Francisco and Boston for 1910, using several different methods of statement.

CHAPTER XI

STATISTICS OF PARTICULAR DISEASES

In studying particular diseases we commonly use four ratios which, though described in different ways, may be distinguished by the terms, (*a*) mortality rate; (*b*) proportionate mortality; (*c*) morbidity rate and (*d*) fatality or case fatality. In addition to these ratios the number of cases of a particular disease may be arranged in groups and classes, by age, sex, nationality, occupation, date of onset and in other ways without using ratios; and the same is true of deaths from a particular disease.

Mortality rate. — The mortality rate for a particular disease is obtained by dividing the number of deaths from that disease by the mid-year population expressed in hundred thousands.

Proportionate Mortality. — The proportionate mortality of a particular disease is the per cent which the number of deaths from that disease is of the total number of deaths from all causes. The interval of time is usually taken as one year, but shorter periods may be used. This method is sometimes spoken of as the "percentage of mortality."

Percentages of mortality are not as commonly published as they were some years ago. They do not involve the population, hence they are especially useful where the population is not known or cannot be correctly estimated. Since the custom of estimating population by a uniform system has become general there has been less need for considering the percentage of mortality. A theoretical disadvantage of the method is the fact that the number of deaths from the particular disease appears in both the numerator and the denominator of the fraction; that is, the number of deaths from the particular disease helps to make up the total number of deaths.

Morbidity rate. — The morbidity rate is the ratio between the number of cases of a particular disease in a year and the mid-year population expressed, in thousands, or better in hundred thousands. It is sometimes called the "case rate." The morbidity rate is very useful in epidemiological investigations. It is usually based on the entire population, but just as in the case of death-rates, or mortality rates, from particular diseases it may be computed for specific age-groups or classes.

Fatality. — The fatality of a disease is the ratio between the number of deaths and the number of cases. It is best expressed as a percentage. The fatality of any disease is far from being the same at all ages.

Example. — In 1915 the population of Cambridge, Mass., was 108,822; the total number of deaths from all causes 1460; the number of cases and deaths from scarlet fever were 379 and 5, respectively. From these facts we have the following rates and ratios:

General death-rate, 1460 ÷ 108.822 = 13.45 per 1000.
Scarlet-fever, mortality rate, 5 ÷ 1.08822 = 4.6 per 100,000.
Scarlet-fever, proportionate mortality, 5 ÷ 14.60 = 0.34 per cent.
Scarlet-fever, morbidity rate, 379 ÷ 1 08822 = 347 per 100,000.
Scarlet-fever, fatality, 5 ÷ 379 = 1.32 per cent.

Inaccuracy of morbidity and fatality rates. — It must not be forgotten that rates for morbidity are based on reported cases and that not all cases are reported. Nearly all morbidity rates are too low. It follows, therefore, that nearly all fatality percentages are too high. In the case of typhoid-fever, for example, a comparison of deaths and reported cases, has led to the popular idea that the fatality is about 10 per cent, that is, one death for every ten cases. But in a number of epidemics, where the cases were accurately obtained by a house to house canvas, it has been found that there were from twelve to fifteen cases for each death, that is, the fatality was only about 7 per cent.

It is interesting to see how an epidemic of typhoid fever will result in an increased proportion of cases being reported. In Cleveland, Ohio, in the year 1902 there were but 3.7 times as many reported cases as deaths, but the following year, when a severe epidemic occurred, there were 7.3 times as many reported cases as deaths. If the figures for 1902 had been correct it would have meant a fatality of 27 per cent, which is most unlikely.

Causes of death in Massachusetts. — In 1920 the principal causes of death in Massachusetts were as follows. They are arranged according to the International List.

TABLE 87

PRINCIPAL CAUSES OF DEATH IN MASSACHUSETTS, 1920

Rank.	Cause of death.	Per cent of mortality.
(1)	(2)	(3)
1	Organic diseases of the heart (79)	11.9%
2	Cancer and other malignant tumors (39–45)	8 4
3	Cerebral hemorrhage and softening (64, 65)	7.8
4	Other diseases of the respiratory system (86–88, 93–98)	7.3
5	Tuberculosis of the lungs (28, 29)	7.0
6	Acute nephritis and Brights disease (128–132)	6.6
7	Pneumonia (92)	5.3
8	Congenital debility and malformations (150, 151)	5 2
9	Violent deaths (suicides excepted) (164–186)	4.8
10	Diarrhea and enteritis, under 2 years (104)	3.1
		67.4

It will be seen that these ten causes account for about two-thirds of all the deaths.

The ten most important causes of death for the U. S. registration area in 1919 were not placed in the same order, but were as follows:

TABLE 88

PRINCIPAL CAUSES OF DEATH: UNITED STATES, 1919

Rank.	Cause of death
(1)	(2)
1	Organic diseases of the heart (79)
2	Tuberculosis of the lungs (28, 29)
3	Influenza (10)
4	Bright's disease (119, 120)
5	Cancer (39–45)
6	Violent deaths (164–186)
7	Cerebral hemorrhage (64, 65)
8	Pneumonia (92)
9	Congenital debility and malformations (150, 151)
10	Other diseases of respiratory system (86, 87, 88, 91, 93–94–98)

The proportionate mortality differs more or less in different places. It is not the same for the two sexes. It differs greatly at different ages. It is not the same at all seasons. It is different to-day from what it was a generation ago. The control of communicable diseases has considerably altered the relative importance of the different causes of death.

Study of tuberculosis by age and sex. — In attempting to study any particular disease in order to determine its relation to age and sex one will be surprised to find how difficult it is to get a complete statement of the necessary facts for any given place. Obviously we need to have both the cases and deaths classified by age and sex, and we also need the population and the deaths from all causes arranged by sex and according to the same age grouping. If we attempt to use the U. S. Census reports we find that no data for cases are given; if we attempt to use the state board of health reports we may find that the deaths are classified by age and sex, but that only the total numbers are given for cases; in some city board of health reports we may find cases and deaths duly classified but no populations given for the corresponding groups and classes. As an illustration of unsatisfactory current practice let us study the statistics of tuberculosis for the city of Cambridge, Mass., for the year 1915. The data in the following table were taken from the annual report of the local board of health, except the population statistics, which were taken from the state census of that year. These data are more than ordinarily complete, yet they are not satisfactory, due chiefly to incomplete reports of cases. It may be assumed that the numbers of deaths are reasonably precise, yet they do not strictly represent local conditions as they include deaths in hospitals.

The numbers of cases and deaths are small and this also makes the derived rates subject to erratic fluctuations.

The fundamental data are given in columns (2) to (9), the derived figures in the subsequent columns. Column (10) was obtained from columns (2) and (8); column (12) from column (8); column (14) from columns (6) and (2); column (16) from column (6); column (18) from columns (6) and (4); column (20) from columns (6) and (8).

If we take the figures at their face value we notice first that both the morbidity and mortality rates are high in infancy and low in childhood. The male morbidity rate reaches its highest point in age group 30–39 years, but the male mortality rate is highest between 40 and 50. In females the morbidity rate rises earlier and is highest in age-group 20–29. The highest female mortality rate is also found in the same group. Forty per cent of all the cases and 37.9 per cent of all the deaths from tuberculosis among females occurred between the ages of twenty and thirty.

If we study the figures for proportionate mortality we see

TABLE 89

CAMBRIDGE, MASS., 1915

Statistics of Tuberculosis (28-35) Cases and Death, Arranged by Age and Sex

Age-group.	Population.		Deaths, all causes.		Tuberculosis Deaths		Tuberculosis Cases.	
	Male	Female.	Male.	Female	Male	Female	Male	Female.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
0–1	1,114	1,080	138	105	0	1	1	1
1–4	4,161	4,120	38	40	2	1	6	1
5–9	4,996	5,000	13	13	0	1	4	5
10–14	4,488	4,533	7	6	1	1	4	0
15–19	4,569	4,901	22	12	9	7	9	17
20–29	10,424	11,326	44	51	23	31	40	50
30–39	8,334	9,190	64	43	29	19	49	31
40–49	6,552	7,177	80	76	32	10	31	9
50–59	4,133	4,823	88	85	13	6	14	8
60–	3,224	4,678	229	306	10	5	9	3
Total	51,995	56,808	723	737	119	82	167	125

Age-group.	Morbidity (case), rate per 100,000.		Percentage distribution of cases.		Mortality (death) rate		Percentage distribution of deaths.		Proportionate mortality, per cent		Fatality, per cent.	
	Male	Female	Male.	Female.	Male.	Female	Male	Female	Male.	Female	Male.	Female.
(1)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)
0–1	90	93	0.6	0 8	0	93	0	1 2	0	1	0	100
1–4	144	41	3 6	0 8	48	41	1 7	1 2	5	3	33	100
5–9	80	100	2 4	4.0	0	20	0	1.2	0	8	0	20
10–14	89	0	2 4	0 0	22	26	0 8	1 2	14	17	25	..
15–19	197	347	5 4	13 6	197	143	7 6	8 5	39	58	100	41
20–29	383	441	23 8	40 0	220	274	19 3	37.9	52	61	57	62
30–39	588	337	29 4	24.8	348	207	24 4	23 2	45	44	59	61
40–49	473	125	18 6	7.2	488	139	26 9	12 2	40	13	103	111
50–59	339	166	8 4	6 4	315	124	10 9	7 3	15	7	92	75
60–	279	64	5 4	2 4	310	107	8.4	6 1	4	2	111	167
Total	321	220	100 0	100.0	229	144	100.0	100.0	16 5	11.1	71	66

that tuberculosis caused 16.5 per cent of all deaths among males and 11.1 per cent of all deaths among females. In age-group 20–29 this disease caused nearly two-thirds of all deaths of females and more than half of all deaths of males. In comparing the figures for proportionate mortality it should be observed that the age-groups are not of equal value throughout the table; some cover ten years, some five, one covers four years, and one only one year.

The fatality rates are practically worthless. Sometimes the number of reported cases was less than the number of deaths, thus making the fatality rate higher than 100 per cent. This would be an absurdity, if we did not know that the tuberculosis deaths of one year may represent cases of the year before or the year before that. Tuberculosis is a disease of long duration, sometimes several years. The fatality of such a disease as this cannot be computed in this way. Yet imperfect as these figures are we can gather from them the main facts. We can see that tuberculosis is essentially a disease of early manhood and womanhood, and at those ages we naturally look to working conditions as contributory factors. The disease continues as an important cause of death up to old age, especially among males.

If we take the figures for the U. S. Registration Area as given in the Mortality Report for 1914 we obtain a more uniform set of figures, as they are based on 898,059 deaths instead of 1460 deaths. (Table 90.) Here the highest proportionate mortality for tuberculosis was for age-group 20–24 years; for males it was 34.3 per cent, for females 39.2. These figures are considerably lower than for Cambridge. The percentage distribution of tuberculosis deaths showed a maximum in age-group 20–24 for females, and in age-group 25–29 for males. The morbidity, mortality and fatality could not be computed as no records of cases and no population by age-groups were given in the Mortality Report.

TABLE 90

DEATHS FROM TUBERCULOSIS OF THE LUNGS (28)

U. S. Registration Area, 1914, by Age and Sex

Age group	Deaths, all causes.		Deaths (28)		Percentage distribution		Proportionate mortality.	
	Male	Female	Male	Female	Male	Female	Male	Female.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
0–4	118,375	95,735	3,416	2,832	6 1	6 9	2 9	3 0
5–9	10,162	9,140	832	878	1 5	2 1	8 2	9 6
10–14	6,819	6,054	702	1,235	1 3	3 0	10 3	20 3
15–19	10,934	10,322	2.719	3,801	4 9	9 2	24 8	36 8
20–24	17,516	15,408	6.002	6.061	10 8	**14 7**	**34 3**	**39 2**
25–29	19,407	16,300	6,634	5,795	**11 9**	14 1	34 0	35 5
30–34	20,212	15,878	6,466	4,701	11 6	11 4	32 2	29 7
35–39	23,154	17,155	6,128	3,922	11 5	9 5	27 8	22 9
40–44	24,116	16,803	5.761	2,950	10 3	7 2	23 8	17 6
45–49	25,283	17,779	4,640	2,172	8 3	5 3	18 3	12 2
50–54	28,809	20,294	3,853	1,679	6 9	4 1	13 4	8 3
55–59	28,896	21,006	2,905	1,388	5 2	3 4	10 1	6 6
60–64	31,255	24,275	2,139	1,217	3 8	3 0	6 8	5 0
65–69	32,728	27,075	1,460	966	2 6	2 3	4 5	3 6
70–74	32.760	29,109	929	777	1 6	1 9	2 8	2 7
75–79	27,365	26,410	515	465	0 9	1 1	1 9	1 8
80–84	19,132	20,537	188	205	0 3	0 5	1 0	1.0
85–89	9,600	11,447	48	57	0 1	0 1	0 5	0.5
90–94	3,129	4,165	9	16		..	0 3	0 4
95–99	704	1,007	6	3				....
100–	179	288	1	2				. .
Total	491,416	406,643	55,724	41,179	100 0	100 0	11 4	10 2

Seasonal Distribution of deaths from tuberculosis. — A natural way of studying the seasonal distribution of deaths from tuberculosis is to subdivide the annual number of deaths into the numbers which occurred each month and then find what per cent each is of the whole. It is common to arrange the results in a horizontal line thus:

TABLE 91

SEASONAL DISTRIBUTION OF DEATHS FROM TUBERCULOSIS (28-35)

U. S. Registration Area, 1914

	Jan	Feb	March	April	May.	June	July	Aug	Sept	Oct	Nov	Dec	Total
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Number of deaths	7522	7524	8537	8238	7782	6901	6528	6209	6031	6009	6212	6873	84,366
Per cent of total for the year	8.9	8.9	10.5	9.8	9.2	8.1	7.6	7.4	7.1	7.1	7.4	8.0	100.0%

These figures show that the largest numbers of deaths occur during the spring months, but the difference between winter and summer is not great. It must not be forgotten in such a comparison as this that the months are of unequal length. While the above figures show that 8.9 per cent of the deaths occurred in February and 10.5 per cent in March the average number of deaths per day was 269 per day in February and 275 per day in March. The U. S. Mortality Report, from which these figures were taken, do not distribute the deaths in each month according to age.

Another way of studying the seasonal distribution is to find the proportionate mortality for tuberculosis for each month.

TABLE 92

PROPORTIONATE MORTALITY FROM TUBERCULOSIS BY MONTHS (28-35)

U. S. Registration Area, 1914

Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
9.1	9.7	9.5	10.1	10.2	13.3	9.3	8.7	8.8	8.8	9.0	9.1	9.4%

Here the highest per cent was found in June. These figures are influenced, of course, by the numbers of deaths from causes other than tuberculosis.

Chronological study of tuberculosis. — The death-rate from tuberculosis has decreased steadily during the last generation in Massachusetts as shown by Fig. 69. This curve does not tell us many of the things which we desire to

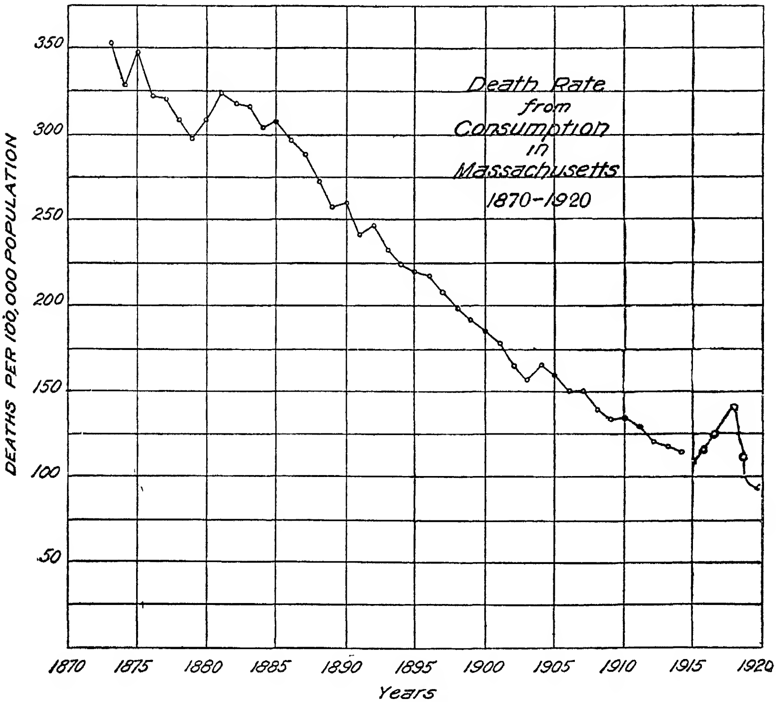


FIG. 69. — Death-rates from Pulmonary Tuberculosis, Massachusetts, 1870–1920.

know. It shows that prior to 1885 the death-rate exceeded 300 per 100,000 but that now it is in the vicinity of 100. It is not decreasing arithmetically, however. Tuberculosis will not disappear by 1940, or thereabouts as one might think by a hasty forward projection of the plotted line.

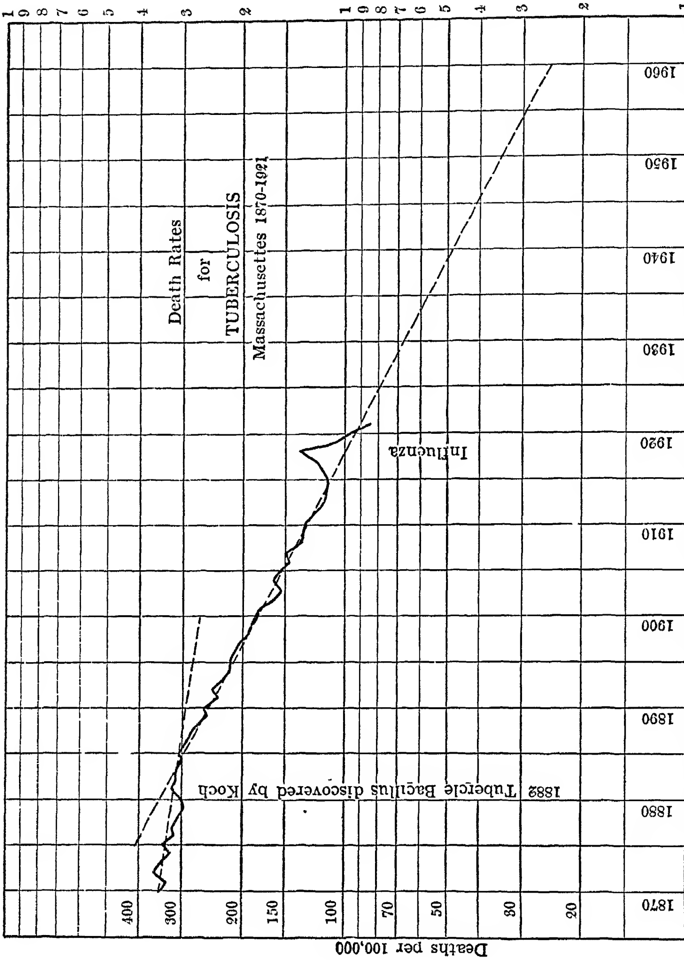


FIG. 70. — Death-rates from Tuberculosis, plotted on Semi-logarithmic Paper. (See Fig. 50).

A much better idea of the chronological changes in the tuberculosis rate can be obtained by plotting the data on semi-log paper as shown in Fig. 70. This shows that before the discovery of the bacillus of tuberculosis in 1882 tuberculosis was high and decreasing slowly, but soon after that the death-rate began to fall and has continued to fall at an almost uniform rate ever since. There have been a few ups and downs, notably at the time of the influenza pandemic, but the uniformity of the decrease leads one to believe that by 1928 the rate will have fallen to 75, by 1938 to 50, and by 1960 to 25 per 100,000.

It is not easy to obtain specific death-rates for tuberculosis by sex and age-groups which cover a long period of years. Even if we had the figures they would not be very reliable because of changes which are being made in the diagnosis of the disease.

Tuberculosis and occupation. — Many misleading statistics relating to tuberculosis and occupation are continually being published. As statements of facts they may be correct, but they are often subject to the fallacy of concealed classification and therefore give false impressions.

A recent report of the New Jersey State Department of Health gives statistics of deaths from tuberculosis in 1916 classified by age and occupation. This is a better arrangement than is sometimes used, but even in studying these figures, it is necessary to be on guard against wrong conclusions because of inadequate data. Thus we find the following:

TABLE 93

DEATHS FROM TUBERCULOSIS CLASSIFIED BY AGE AND OCCUPATION: NEW JERSEY, 1916

Class.	Age.									
	Total	10–19	20–29	30–39	40–49	50–59	60–69	70–79	80–89	90+
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Farmers . .	47	2	6	1	9	11	9	6	3	0
Farm laborers. . . .	11	2	2	3	1	2	1	0	0	0
Clerks	110	11	45	31	20	2	1	0	0	0
Housekeepers and stewards.	858	34	276	269	158	65	36	18	1	1
General laborers . .	364	12	61	96	115	49	27	4	0	0
Stone cutters. . .	19	0	0	2	4	7	5	1	0	0

Why is the number of deaths from tuberculosis so high among housekeepers? Not because housekeeping imposes a special hazard, but because there are so many housekeepers in the state. Obviously what is needed here are the specific rates for this particular disease by age-groups. But to compute them it is necessary to know how many housekeepers there are in the state in each age-group, and who knows these facts? Also are the "stewards" referred to male or female?

Why is the number of deaths among stone cutters so small? This occupation is certainly hazardous from the standpoint of tuberculosis, as the fine, sharp, stone dust tends to lacerate the lungs. We cannot draw any reliable conclusion from the figures because we do not know how many stone cutters there are in each group.

We notice that the largest number of deaths from tuberculosis among farmers occurred in age-group 50–59, but that among farm laborers in age-group 30–39. What is a farmer and what is a farm laborer? We must know that. Also do farm laborers ultimately become farmers? Is there a shifting of individuals from one class to the other as they grow older?

So also in the case of clerks. The largest number of deaths is in age-group 20–29. Do the clerks die off at this early age or do they cease to be clerks? Are the clerks male or female?

The student of statistics must persistently cultivate this critical faculty until it becomes a habit. It may result in a cynical and pessimistic frame of mind in regard to published vital statistics, but even this is better than an easy lapse into an unthinking acceptance of all statistics at their face value. Statistics should be used with truth or they had better not be used at all.

Racial composition of population and tuberculosis death-rate. — The following interesting and at first puzzling situation will serve to emphasize the importance of the careful analysis of death-rates and the necessity of taking into account not only specific death-rates but the composition of the population.

In 1910 the death-rate from tuberculosis of the lungs was 226 per 100,000 in Richmond, Va., and 187 in New York City, and yet the specific death-rates from this disease for both white and colored persons were greater in New York than in Richmond. The following figures were taken from the U. S. Census reports.

TABLE 94

TUBERCULOSIS DEATH-RATES IN NEW YORK AND RICHMOND

Class.	Population.		Number of deaths.		Death-rate per 100,000.	
	New York.	Richmond.	New York.	Richmond.	New York.	Richmond.
(1)	(2)	(3)	(4)	(5)	(6)	(7)
White......	4,675,174	80,895	8368	131	179	162
Colored.....	91,709	46,733	513	155	560	332
Total	4,766,883	127,628	8881	286	187	226

The explanation of this anomaly lies, of course, in the fact that in Richmond more than one-third of the population is colored, while in New York the colored population is less than two per cent.

Many similar comparisons can be found between northern and southern cities. This is merely a striking case.

Diphtheria in Cambridge, Mass. — Applying the same methods to the study of diphtheria we have the following figures:

TABLE 95

CAMBRIDGE, MASS., 1915

Statistics of Diphtheria, Cases and Deaths Arranged by Age and Sex

Age-group.	Population		Deaths, all causes.		Deaths from diphtheria		Cases of diphtheria	
	Male	Female.	Male.	Female.	Male.	Female	Male	Female.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
0–1	1,114	1,080	138	105	1	3	7	4
1–4	4,161	4,120	38	40	4	6	56	67
5–9	4,996	5,000	13	13	5	5	63	80
10–14	4,488	4,533	7	6	1	1	15	24
15–19	4,569	4,901	22	12	1	0	7	4
20–29	10,424	11,326	44	51	1	0	8	12
30–39	8,334	9,190	64	43	0	0	4	5
40–49	6,552	7,177	80	76	0	0	0	1
50–59	4,133	4,823	88	85	0	0	0	1
60–	3,224	4,678	229	306	0	0	0	0
Total	51,995	56,808	723	737	13	15	160	198

Age-group.	Morbidity (case) rate per 100,000		Percentage distribution of cases.		Mortality (death) rate.		Percentage distribution of deaths.		Proportionate mortality, per cent.		Fatality, per cent.	
	Male.	Female.	Male.	Female.	Male	Female	Male.	Female.	Male.	Female	Male.	Female.
(1)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)
0–1	629	371	4 4	2 0	90	278	7.7	20 0	0.7	2 8	14	75
1–4	1340	1630	35.0	33 9	96	146	30 7	40 0	10 5	15 0	7	9
5–9	1262	1600	39.3	40 4	100	100	38 5	33 3	38 4	38.4	8	6
10–14	334	528	9 4	12 1	22	22	7 7	6 7	14.3	16 7	7	4
15–19	153	82	4 4	2 0	22	0	7 7	0 0	4 5	0 0	14	0
20–29	76	106	5 0	6 1	9	0	7 7	0 0	2 2	0 0	13	0
30–39	48	55	2 5	2 5	0	0	0 0	0 0	0 0	0.0	0	0
40–49	0	14	0 0	0 5	0	0	0 0	0 0	0 0	0.0	0	0
50–59	0	21	0 0	0 5	0	0	0 0	0 0	0.0	0 0	0	0
60–	0	0	0 0	0 0	0	0	0 0	0.0	0 0	0 0	0	0
Total	308	349	100 0	100 0	25	26	100 0	100 0	1.8	2.0	8	7

Here we see that the maximum age incidence occurs between the ages of one and ten for both males and females. The morbidity rate in Cambridge for this year was higher for females than for males, but the percentage distribution of the cases was about the same for the two sexes. The mortality rates followed the morbidity rates rather closely, and the fatality was fairly constant except for infant females. The proportionate mortality was highest in age-group 5–9. It must be remembered that these rates are computed from small numbers of cases and deaths, hence no very uniform or significant conclusions can be drawn from them. It is only by using large numbers of events that significant tendencies can be shown. The differences between the occurrence of diphtheria and tuberculosis are, however, very striking.

The seasonal distribution of reported cases of diphtheria was as follows:

TABLE 96

SEASONAL DISTRIBUTION OF DIPHTHERIA CASES: CAMBRIDGE, MASS., 1915

	Jan.	Feb.	March.	April.	May	June	July	Aug	Sept	Oct	Nov	Dec.	Total.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Number of cases	24	35	37	44	31	32	21	15	20	25	38	36	358

It will be noticed that the lowest numbers were reported during the summer vacation months.

Knowing that the incidence of the disease was greatest during the school ages does this indicate that schools played an important part in spreading the infection? Do these statistics *prove* it? If not, what other statistics would be necessary to prove it?

Age susceptibility to diphtheria. — Dr. Charles V. Chapin the Superintendent of Health, of Providence, R. I., has been in the habit of computing what he calls the *attack rate*. This is a ratio between the number of cases and the number of persons exposed, that is, all the members of the family where the disease occurred, including the cases and those who were removed from home after the disease developed. The following figures, given in Dr. Chapin's report for the year 1915, are based on a study of 53,280 exposed persons during 1889–1915.

TABLE 97

DIPHTHERIA ATTACK RATE: PROVIDENCE, R. I., 1915

Age-group.	Attack rate (per cent).	Age-group.	Attack rate (per cent).
(1)	(2)	(1)	(2)
0–1 yr.	16.70	12+ yr.	31.12
1+	43.65	13+	26.08
2+	54 55	14+	22 41
3+	55 61	15+	18 92
4+	55 91	16+	18.58
5+	53 99	17+	17 85
6+	53 82	18+	16 86
7+	49.33	19+	17.33
8+	44 31	20+	23 56
9+	40 91	Adults	6.83
10+	36 42	Total	25 45
11+	35 35		

These figures indicate that the chance of exposed persons acquiring the disease in recognizable form is highest at age four and decreases steadily as the age increases. At the most susceptible period more than half of those exposed came down with diphtheria.

It was found that between the years 1889 and 1915 out of 6822 families who lived in houses where the disease existed in other families, only 474 of these exposed families were attacked. This is only 6.9 per cent. In most of these cases of attacked families there had been some sort of intercourse with the infected families, that is enough to transmit the disease by contact.

Fatality of diphtheria. — Dr. Chapin has also kept a careful record of the fatality of diphtheria in Providence. In 1884 it was 30 per cent, and a few years later it rose to 42 per cent. Between 1895 and 1896 it dropped from 20 per cent to 14 per cent, since which date it has fallen until now it is only about 8 per cent, that is, there is only one death for each 12 cases. The fatality is not the same at all ages as the following table [1] shows:

TABLE 98

DIPHTHERIA CASE FATALITY AT DIFFERENT AGES

Age.	1889–1914.			1915.		
	Cases.	Deaths.	Fatality.	Cases	Deaths	Fatality.
(1)	(2)	(3)	(4)	(5)	(6)	(7)
0–1	280	96	34 28	21	2	9 52
1+	706	247	34.99	43	6	13.95
2–4	3,322	697	20 98	181	24	13 26
5–9	4,541	460	10 13	219	15	6 85
10–14	1,801	83	4 61	9	3	3 79
15–19	616	26	4.22	20	1	5 00
20+	1.670	40	2.39	62	2	3.23
Total	12,936	1649	12 74	625	53	8 48

The greatest decrease in the fatality of the disease has occurred among young children.

To a large extent the decreased fatality has been due to the use of antitoxin, which decreased the number of deaths. To some extent it may have been due to better diagnosis by

[1] Ann. Report Providence Supt. of Health, 1915, p. 64.

culture. If this practice increased the number of recognized cases it would decrease the fatality rates.

Diphtheria is a short disease. Hence the fatality can be computed far more accurately than in the case of tuberculosis.

Chronological study of diphtheria. — Fig. 71[1] shows the decrease in the death-rate from diphtheria in Massachusetts since 1873. In 1876 the rate was very high, about 195 per 100,000. It has decreased very greatly until now it is usually less than 20 per 100,000. Recurrences of diphtheria have occurred at intervals of five or six years. After the great epidemic of 1876 there was no important recurrence until 1889, but after that recurrences were noted in 1894 and 1900. Since then, thanks no doubt to preventive medicine, the recurrences have been so slight as to be almost unnoticed.

What is the reason for these recurrences, for this periodic development of diphtheria? In a general way, whooping cough, scarlet fever, measles, all children's diseases, have similar recurrences. It is commonly explained on the theory of susceptibility. It has already been seen that the rate of attack of exposed persons is very high among young children. It is known, too, that one attack usually makes the victim relatively immune against a second attack. After a period of relative quiescence during which the class of susceptible children has been annually recruited it is natural to expect that an epidemic may spread. This is apparently what happened until the methods of preventive medicine came to be generally used. It probably still happens, but to a less extent than formerly.

Urban and rural distribution of diphtheria. — It is not easy to obtain complete statements of the facts to show the differences between the occurrence of diphtheria in cities and

[1] State Sanitation, Vol. I, p. 167.

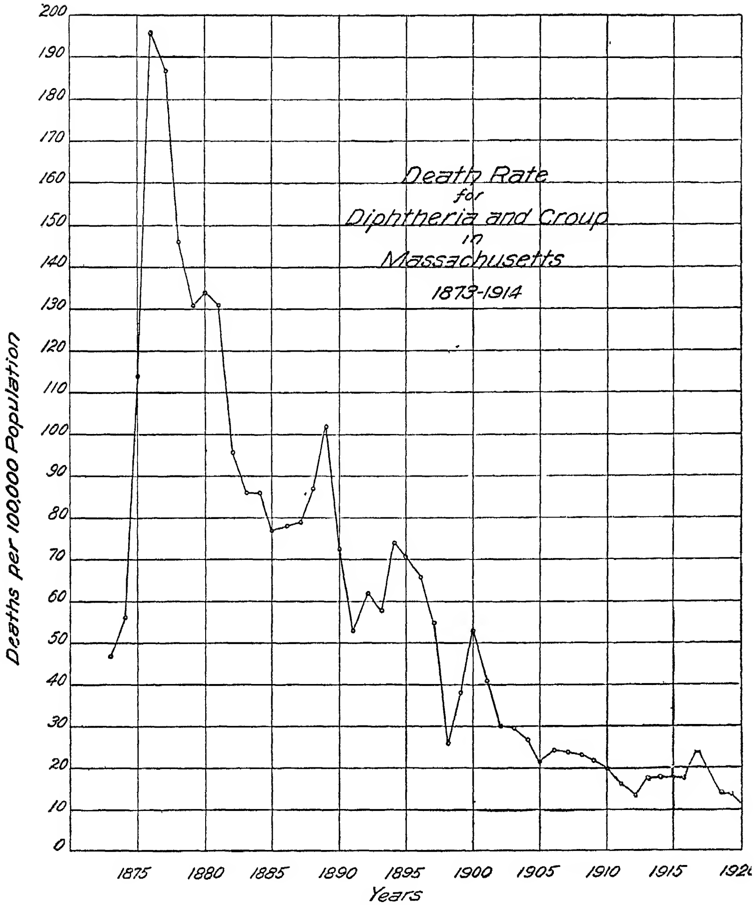


FIG. 71. — Death-rates from Diphtheria, Massachusetts, 1873–1920.

rural districts. Occasionally partial statements are published. In the annual report of the Michigan State Board of Health for 1916–17 it is stated that for the period 1904–15 the morbidity rate was 213 per 100,000 in urban districts and 82 in rural districts; the mortality rates for 1908–1915 were 16.2 and 12.2 per 100,000 respectively. The fatality was 10.9 per cent for cities and 15.7 for urban districts. No separations were made according to age and sex and it is difficult to find these facts. There is, however, quite a difference in the age distribution of diphtheria between the city and the country. In general the average age of diphtheria cases, as well as of persons dying from this disease, is lower in the city. The following facts were taken almost at random from the Mortality Statistics of 1914:

TABLE 99

PERCENTAGE AGE DISTRIBUTION OF DEATHS FROM DIPHTHERIA

Age.	Cities.		Rural states.		
	New York.	Boston.	Vermont.	New Hampshire	Maine.
(1)	(2)	(3)	(4)	(5)	(6)
0+	10 7	7.7	0.0	6.7	9.3
1+	25 9	21 4	5.2	17.8	10 5
2+	16.5	13.7	18 4	11 1	16 3
3+	13.7	14 9	18.4	8 9	9.3
4+	9 7	6 0	13 1	17 8	7 0
5–9 (av. per yr.)	3.7	5 3	6.3	4 0	7 0
10–19 "	0 26	0 6	0 52	1 55	0.7
20–29 "	0 14	0 12	0 0	0 0	0 23
30–39 "	0.05	0 06	0 0	0 0	0 23

Statistical study of typhoid fever. — Typhoid fever has been given a great deal of attention from the statistical point of view. Hundreds of scientific papers describing local outbreaks of the disease, variations in the typhoid fever death-rate and so on have been published. For the most part these have been extensive and not intensive studies. It is rather surprising, when we view this enormous mass of statistics, how little we know about certain important points, such as the morbidity and fatality rates at different ages. Our interest has been engrossed by the more important matter of causation. There are many ways in which the disease may be communicated from one person to another and this question must be answered for each particular outbreak or epidemic. The interest in statistical studies of typhoid fever has, therefore, centered around the subject of correlation, a phase of statistics which we shall consider in Chapter XIV. It will be useful to consider at this point some of the fundamental relations of this disease to human beings. Those who are interested in the epidemiology of the subject are referred to the author's book on Typhoid Fever. This book, it should be said, is to-day somewhat out of date, although its historical value remains.

Age distribution of typhoid fever. — The largest number of deaths from typhoid fever is generally found in age-group 20–29 years. Table 100 shows the percentage distribution of deaths by ages according to the U. S. Census [1] for 1900.

In the case of epidemics caused by a widely scattered infection, as through the public water-supply, the age distribution of the deaths usually approximates these figures. If, however, the outbreak occurs in a school-house or is caused by infected milk, which is used more freely by children than by adults, the larger numbers of deaths may occur in the lower ages; in fact, this is a test often applied in the study of typhoid fever outbreaks.

[1] Vital Statistics, Vol. III, Part I, page cxlvi.

TABLE 100

PERCENTAGE DISTRIBUTION OF DEATHS FROM TYPHOID FEVER; UNITED STATES: 1900

Age-group.	Per cent of deaths	Age-group	Per cent of deaths
(1)	(2)	(1)	(2)
0–4	4 09	50–54	3 52
5–9	5 05	55–59	2 55
10–14	5 20	60–64	1 95
15–19	11 23	65–69	1 12
20–24	17 78	70–74	0 91
25–29	15 09	75–79	0 34
30–34	11 46	80–84	0 11
35–39	9 12	85–89	0 09
40–44	5 77	Total	100 00
45–49	4 62		

If we take the specific death-rates by sex and ages we obtain the following figures:

TABLE 101

SPECIFIC DEATH-RATES FOR TYPHOID FEVER

United States: 1900

Age-group.	Rate per 100,000.		Age-group.	Rate per 100,000.	
	Males.	Females.		Males	Females.
(1)	(2)	(3)	(1)	(2)	(3)
0–4	12	16	45–49	34	29
5-9	15	21	50–54	30	30
10–14	17	31	55–59	30	33
15–19	45	53	60–64	29	33
20–24	66	57	65–69	22	40
25–29	61	48	70–74	27	43
30–34	53	43	75–79	20	23
35–39	48	39	80–84	10	26
40–44	34	37	85–89	16	35

It will be noticed that these differences are not as great as in the previous table. This is because there are fewer persons living at the ages above 50 and even if the specific rate remained high there would not be as many deaths. It is for this reason that both the age distribution of deaths and the specific death-rate are important tabulations. The specific rates just given represent practical conditions and take into account the important element of exposure. The difference between the death-rates of males and females at ages 25–29 must not be regarded as having a physiological basis, for at those ages males are more exposed to the disease than females.

Except at times of epidemics typhoid fever is not a well-reported disease. It is difficult therefore to obtain reliable specific morbidity rates by sex and ages. Such as have been computed, however, show an age distribution very similar to that of deaths, but with a tendency towards larger percentages of cases in the earlier years.

The fatality of the disease at different ages is not as well-established as it ought to be. Computations by Newsholme, by A. W. Freeman[1] and others seem to warrant the following approximate figures; but according to the author's experience they are too high. Their value is largely relative.

TABLE 102

APPROXIMATE CASE FATALITY IN TYPHOID FEVER

Age.	Per cent.	Age.	Per cent.
(1)	(2)	(1)	(2)
0	15	40	21
10	8	50	25
20	15	60	42
30	18	All ages	14

[1] Case Fatality in Typhoid Fever, Public Health Reports, Dec. 8, 1916.

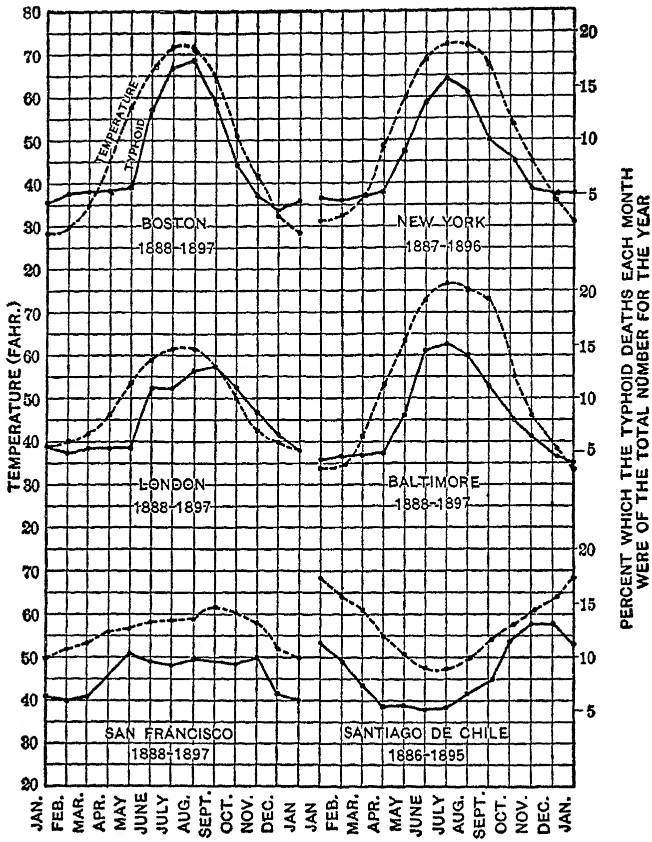


FIG. 72. — Diagram Showing the Relation between Atmospheric Temperature and Seasonal Distribution of Typhoid Fever. (After Sedgwick and Winslow.)

It is probable, therefore, that there is much unreported typhoid fever among children, some of it doubtless unrecognized.

Seasonal distribution of typhoid fever. — The seasonal distribution of typhoid fever appears to be closely related to the manner in which the infection is communicated. Normally there appears to be a fairly close relation between typhoid death-rates and atmospheric temperature, as shown in Fig. 72. Water-borne typhoid is most common during the colder months of the year. Examples of seasonal distribution of typhoid fever are to be found in many epidemiological studies.

Chronological reduction in typhoid fever. — The reduction in the amount of typhoid fever in the United States during the last twenty-five years has been general and steady. From being one of our most dreaded diseases it seems likely to almost disappear. This has been due to many things. George A. Johnson,[1] in an exhaustive compilation of statistics, gave the chief credit to the purification of public water supplies by filtration, his conclusions being summed up in Fig. 73. His main contention is doubtless correct, but the purification of water is only one of many factors in the problem. The safeguards thrown around milk and other foods, the better understanding of the idea of contact, the constantly decreasing number of typhoid carriers since the Civil War and since the purification of water-supplies, the recent extensive use of vaccination methods, have contributed to the present low and falling death-rates. The typhoid-fever death-rates in many cities using unfiltered water-supplies have fallen along with the others.

Fig. 74 shows the decrease in typhoid fever in Massachusetts since 1880 plotted on semi-log paper. The high-rate which prevailed after the war was gradually falling in an

[1] The Typhoid Toll, Jour. Am. Water Works Assoc., June, 1916.

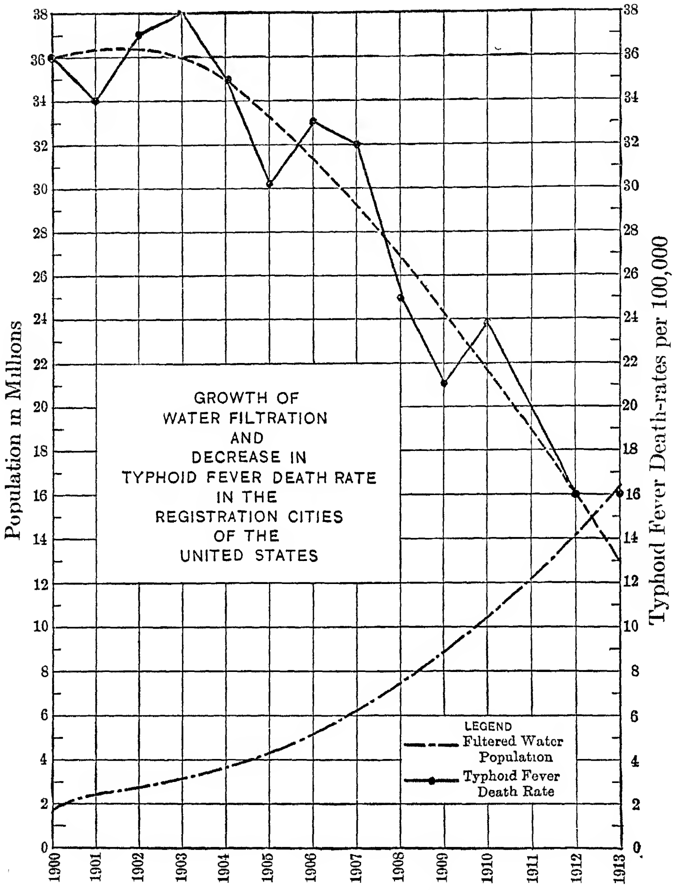


FIG. 73.—Relation between Typhoid Fever and Water Filtration. After Johnson.

irregular way, but about 1888 following the early sanitary work of the State Board of Health, it took a new downward slope. This continued until about 1908, when campaigns in favor of cleaner milk, especially Pasteurized milk, resulted

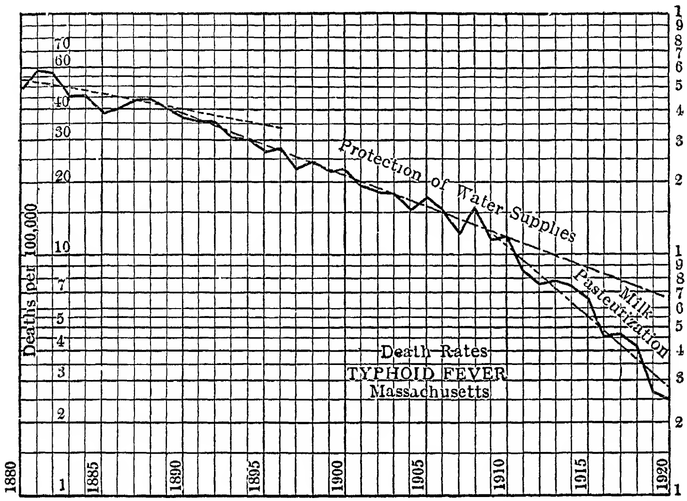


FIG. 74. — Death-rates from Typhoid Fever, plotted on Semi-logarithmic paper.

in giving the typhoid rate a new downward slope. Similar diagrams for other states and cities enable one to detect the separate effects of such measures as water filtration, water chlorination, milk pasteurization, and even typhoid vaccination.

Statistics of cancer. — Let us now take up a disease which is quite different from tuberculosis, diphtheria and typhoid fever, namely, cancer. This involves some interesting applications of statistical principles. The subject is one which demands most careful investigation and the reader should by all means read a paper on "The Alleged Increase of Cancer," by Prof. Walter F. Willcox, of Cornell University, as a splendid example of critical work.[1]

Extensive studies of death-rates have shown that as a *reported* cause of death cancer is on the increase. Dr. F. L. Hoffman in a most elaborate monograph entitled "The Mortality of Cancer throughout the World,"[2] has demonstrated this fact. But is this reported increase an actual increase? Is it due to changing conceptions of the statistical unit, to a better recognition of the disease, to differences in the composition of populations? Messrs. King and Newsholme,[3] take the ground that the alleged increase is due to statistical fallacies. Their conclusion is based on intensive studies. Willcox, in the article referred to, has made a critical comparison of these two points of view, and his conclusions are that "improvements in diagnosis and changes in age composition explain away more than half and perhaps all of apparent increase in cancer mortality." Dr. Stevenson[4] has found, however, that in England and Wales the increase in "accessible cancer" among males has been greater than that of "inaccessible cancer."

It is admitted at the start that no reliable statistics of cancer morbidity exist. Therefore, neither morbidity nor fatality rates can be computed. The entire discussion rests on deaths.

The increase in reported deaths from cancer is well shown by the following figures:

[1] Quar. Pub. Am. Sta. Asso., Sept. 1917, Vol. XV, p. 701.
[2] Published in 1915, by the Prudential Press, Newark, N. J.
[3] Proc. Royal Society, 1893, liv, pp. 209–242.
[4] Report of Registrar General England and Wales, 1917.

TABLE 103

DEATH-RATES FROM CANCER

U. S. Registration Area of 1900

Year.	Rate per 100,000.	
	Male	Female.
(1)	(2)	(3)
1900	47 0	80.7
1905	53 0	92.1
1910	62.6	103 7
1915	72.3	111.9

The death-rate for females is considerably higher than for males.

The specific death-rate by ages and sex runs as follows:

TABLE 104

SPECIFIC DEATH-RATES FOR CANCER

U. S. Registration Area of 1900 for the Year 1910

Age-group.	Rate per 100,000.		Age-group.	Rate per 100,000.	
	Male.	Female.		Male.	Female.
(1)	(2)	(3)	(1)	(2)	(3)
0–5	4 1	2 8	35–44	33 0	88.9
5–9	1.5	1.2	45–54	106 7	230 7
10–14	1.8	1 4	55–64	272 0	411 3
15–19	2 9	3.5	65–74	493 6	616 2
20–24	4 9	4 1	75–	693.7	867.8
25–34	9.5	21 9			

By applying the method of adjustment to the Standard Million of Population, Willcox finds that for England and Wales in 1911 the death-rate from cancer should have been

91.5 instead of 99.3 per 100,000. In 1901 it was 84.3; hence the increase, instead of 17.8 per cent, would have been 8.7 per cent if computed on the basis of similar populations. Similar comparisons are made for other populations, from all of which the conclusion is drawn that about one-third of the increase in all the populations considered is due to changes in sex and age composition.

In regard to diagnosis many interesting facts are presented. There are differences between the statistics for accessible and inaccessible cancer, the increase being chiefly in the latter. "Laymen seldom report cancer as a cause of death," and there appears to be a correlation between cancer increase and an increase in the number of physicians per 100,000 of population, and the number of medical certificates signed by competent persons. The increase in hospitals is also a factor. Deaths ascribed to tumor, and to "old age," have been decreasing, as cancer has increased, and the implication is that there has been a shifting of these statistical units. For all of these deaths the reader should consult Willcox's paper. He gives also, by way of analogy, a comparison between cancer and appendicitis, which shows that the rate of increase in reported causes of death are substantially the same for the two diseases, namely, 44 per cent and 40 per cent respectively between 1900 and 1915. The upshot of this investigation is that there is no more reason for people to fear dying from cancer now than there was a generation ago. The disease has not changed, people have not changed; it is the reports of the physicians which have changed because of their increased knowledge. Is this the last word on the subject? Probably not.

Further studies of particular diseases. — It is not possible to take up the hundred or more particular diseases and discuss them by means of statistics. This, however, is one of the chief uses of vital statistics. Enough has been given perhaps to illustrate the method of procedure, and to emphasize the importance of critical statistical analysis. The necessity of considering specific rates, and varying compositions of populations in all these studies cannot be too strongly insisted on.

The student will find it a fascinating and highly valuable study to take up some disease in which he may be interested and study it intensively. There is room in statistical literature for many monographs treating of the statistics of particular diseases.

EXERCISES AND QUESTIONS

1. Describe the cycles of whooping cough in New York State since 1885. [N. Y. State Dept. of Health, Monthly Bulletin, March 1917, p. 70.]

2. How would you find out what proportion of all children born have whooping cough at some time in their lives? Try to make up a table from morbidity statistics of whooping cough classified by age in years, and see if you cannot determine this. Select, for example, the year 1910. How many babies were born that year and how many had had whooping cough while infants? In 1911 how many cases of whooping cough were in age-group 1–2; in 1912 how many in age-groups 2–3, etc.? Add these together and compare the result with the births in 1910. Then do the same starting with 1909, and then 1908, etc. Compare all the results. Are they more uniform than the ordinary annual statistics for whooping cough?

3. Make the same sort of study for measles.

4. Make the same sort of study for diphtheria.

5. Make the same sort of study for scarlet fever.

6. Compare death-rates for whooping cough, measles, etc., in urban and rural districts. What foundation is there for Farr's law that contagious diseases increase as the density of population?

7. Explain the recent finding that the death-rates from measles in the U. S. army cantonments has varied inversely as the density of population (percentage of urban population) in the states from which the soldiers came.

8. Describe the periodicity of whooping cough in Sweden. (See Stephenson and Murray's Textbook of Hygiene.)

9. Describe the age distribution of Pellagra. [See Amer. J. P. H., July, 1918, p. 488.]

10. What reduction in diphtheria has occurred as a result of the use of anti-toxin. [See Am. J. P. H., May, 1917, p. 445.]

11. Is appendicitis increasing? [See Am. J. P. H., July, 1916.]

12. Make a statistical summary of the influenza epidemic of 1889–90. Consult reports of state and city departments of health.

13. Make a statistical study of the influenza epidemic of 1918 for some state, city or town.

14. Prepare a short statistical summary of cancer, — its geographical distribution, its occurrence among different age-groups, its chronology, etc. [Hoffman, Frederick L. The Mortality from Cancer throughout the World. Newark. The Prudential Press, 1915.]

CHAPTER XII

STUDIES OF DEATHS BY AGE PERIODS

Infant mortality. — No part of vital statistics is attracting more attention nowadays than the subject of infant mortality. It is, indeed, a serious problem and worthy of most careful study. It is a complex problem and one difficult to understand. It is a problem which goes beyond itself. Newsholme says that "infant mortality is the most sensitive index of social welfare and of sanitary improvements which we possess." Another says that "infant mortality is to the health officer what the clinical thermometer is to the physician." People who will not take care of their offspring will not take care of themselves.

Some definitions. — The term infant is applied to any child from the day of its birth up to one year of age. Statistically a child born dead is not included among either births or deaths; it is a still-birth. But if the child is born alive and dies almost immediately it is to be regarded as an infant and both its birth and its death is to be recognized statistically. In the past health officials were not careful to make this distinction and many of the old statistics are for that reason not comparable with present-day records. This should be kept in mind in comparing statistics which extend over long periods of time.

The specific death-rate for infants, that is, for age-group 0–1, is computed in the same way as the specific death-rate for any other age-group, namely, by dividing the annual number of deaths in the group by the mid-year population of the group, expressed in thousands. By *infant mortality*, as the term is generally understood, is meant something slightly different, namely, the number of infant deaths in a calendar year divided by the number of births during the same year.

Prenatal deaths. — Fœtal deaths which occur before the sixth or seventh month of gestation are known as miscarriages and are not reportable or recognized in ordinary statistical work; those which occur later than this are called still-births and must be reported. The time limit is sometimes stated as twenty-eight weeks, sometimes it is made dependent upon the apparent condition of the fœtus. A still-birth, although reportable both as a birth and a death, should always be kept apart from true births in tables of statistics.

The following figures show how in Boston the ratio of still-births to total population and the ratio between still-births and living births have changed during the last thirty years.

TABLE 105

STILL-BIRTHS, BOSTON

Year.	Number per 100 living births.	Number per 1000 inhabitants.	Year.	Number per 100 living births.	Number per 1000 inhabitants.
(1)	(2)	(3)	(1)	(2)	(3)
1891	4 2	1.3	1904	4 0	1 1
1892	4 2	1.2	1905	4 2	1.1
1893	4 1	1.3	1906	3 8	1.1
1894	4 5	1.4	1907	4 0	1 2
1895	3 8	1 2	1908	3 4	1.0
1896	3 9	1.3	1909	4 0	1.1
1897	3 6	1.2	1910	3.0	1.0
1898	3 7	1.1			
1899	3 3	1 0			
1900	3 5	1 0			
1901	3.6	1.0			
1902	3.9	1 1			
1903	4 0	1.1			

The monthly records show no appreciable variation in the rate of still-births during the year. The ratio of still-births to living births is much greater for illegitimate than for legitimate children, especially among mothers less than twenty years of age. There are marked differences in the still-birth rates in different countries.

At Johnstown, Pa., 4.5 per cent of all births were still-births, and 8.7 per cent of all mothers reporting had suffered miscarriages.

The percentages of still-births arranged according to the age of the mothers gave the very high percentage of 11.1 per cent for mothers under 20 years of age, 4 per cent for age group 20–24, 5.1 for 25–29 years, 4.4 for 30–39 years, and 3.3 for ages over 40. The percentage for native mothers was 5.2 per cent, for foreign mothers, 3.8 per cent.

Infant mortality and the specific death-rate for infants. — There are two reasons why the specific death-rate for age group 0–1 year is not used more. There is the difficulty of finding the actual number of infants alive at the middle of any calendar year. Of course, a census might be taken on July 1, but even that figure would not be very satisfactory for births are not uniformly distributed through the year and the ages of infants are often given incorrectly. It is possible to compute the number alive July 1 from the monthly records of births and deaths, but rarely, if ever, in this country are the data for doing this published. The reports of vital statistics of Hamburg contain each year a table like that shown in Table 106 from which this computation can be made.

Starting in 1911 we see that in January 1853 children were born, of which 260 died the same year; 5, however, died in January, 1912, before reaching their first birthday. Of the children born in February, 1911, 8 died in January, 1912, and 3 in February, 1912. By keeping up this tabulation we

TABLE 106

BIRTHS AND DEATHS OF CHILDREN UNDER ONE YEAR

Hamburg, 1911 and 1912

Year and mo	Births.	Died in 1911.	Died in 1912 before reaching age of one year.													Died in first year.	Reached the first year alive.		Living Jan., 1913.
			J	F	M	A	M	J	J.	A	S.	O.	N.	D.	Total		No.	%	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
1911.																			
Jan.	1,853	260	5												5	265	1,588	85 70	. .
Feb.	1,700	254	8	3										.	11	265	1,435	84 41	. ...
Mar.	1,752	253	4	6	6							.			16	269	1,483	84 65	.....
April	1,713	250	6	4	12	3									25	275	1,438	83 95	....
May	1,777	251	11	3	10	43									31	282	1,495	84 13	....
June	1,670	242	11	8	11	7	8	0							45	287	1,383	82 81	....
July	1,791	255	14	8	9	10	4	13	4						62	317	1,474	82 30	....
Aug.	1,760	188	15	10	12	6	9	8	6	4					70	258	1,502	85 34	....
Sept	1,670	124	18	11	8	8	11	6	2	7	2				73	197	1,473	88 20	....
Oct.	1,668	131	19	18	17	6	14	5	8	4	6	2			99	230	1,438	86 21	.
Nov.	1,603	90	27	27	8	16	8	15	9	8	7	5	3		133	223	1,380	86 09	.....
Dec.	1,705	58	53	27	25	14	10	7	13	9	3	10	6	2	179	237	1,468	86 10	. ..
Sum	20,662	2356	191	125	118	74	67	54	42	32	18	17	9	2	749	3105	17,557	84.97	. .
1912.																			
Jan.	1,829		78	45	30	19	17	13	12	9	8	4	9	3	247	. ..	. ..	.	1,582
Feb.	1,722	.		56	44	20	12	15	15	15	9	4	6	3	199	.	. ..	.	1,523
Mar.	1,810	.			63	29	21	20	15	19	7	6	15	6	201	....	. ....	....	1,609
April	1,721	.				57	37	17	20	19	6	7	6	8	177		. .	.	1,544
May	1,723	.					76	26	20	28	12	12	13	8	195	.	.		1,528
June	1,777							60	41	26	21	19	7	12	186	...	.	.	1,591
July	1,833								68	43	21	19	16	11	178	.	.	.	1,655
Aug.	1,817									70	25	30	20	21	166		.		1,651
Sept.	1,748	.	.								67	27	25	22	141	...	. . .	...	1,607
Oct.	1,781		.									71	38	33	142	.	... .	..	1,639
Nov.	1,688	.				.				.			69	35	104	.	... .	.	1,584
Dec.	1,799		.									.		70	70				1,729
Sum	21,248		78	101	137	125	163	151	191	229	176	199	224	232	2006		.	...	19,242
Died in year 1912			269	226	255	199	230	205	233	261	194	216	233	234	2755				

obtain all the deaths in 1912 of babies born in 1911. In the same way we obtain the deaths in 1912 of infants born in 1912. These added to the preceding give us all the infant deaths for 1912, namely, 2755. The number of children living Jan. 1, 1913, was 21,248 − 2006, or 19,242. By starting with July 1, 1911, we could obtain the number of infants living July 1, 1912. It requires monthly records extending over two calendar years to get this result, and even after we get it it may not be exact as there may have been errors in the records.

The *infant mortality* is much simpler to compute, but it is not without its errors. Birth reporting is notoriously bad, and there is often doubt as to the stated age of the dying child. Children within a few months of their first birthday are sometimes said to be a year old.

In the long run, the average specific death-rates for age group 0–1 agree fairly well with the infant mortalities, but in any particular place and year they may vary from each other as much as twenty-five or fifty per cent. The infant mortality should be stated in whole numbers as the accuracy of the data does not warrant the use of decimals.

The deaths of infants in one year will include some who were born in the preceding year. In our infant mortality ratios, therefore, we are not dealing wholly with the same infants in the denominator and numerator. Fluctuations in the birth-rate in successive years may influence this ratio.

First-year death-rate. — In the case of Hamburg we see from the table that in the year 1912 there were 21,248 births and 2755 infant deaths. From these figures we may compute the infant mortality ratio in the usual way and obtain 130 per 1000. Yet if we consider the 20,662 births in the twelve months of 1911 and follow them through their first year, we find that 3105 died, that is the ratio was 150 per 1000. In other words, 850 per 1000, or 85 per cent reached, their first year of life.

In the printed table we find in the last column for 1911 figures which show these percentages by months. It is interesting to notice how this percentage of born children who reach their first year varies with the season. According to the 1911 figures for Hamburg, September is the most favorable month for a birth because 88.2 per cent of the children born that month reached the age of one year; 118 per thousand died. July is the most unfavorable month as only 82.3 per cent reached the first year; 177 per thousand died.

Very few American cities keep their records in such shape that facts like these can be easily secured. In Hamburg they publish both the infant mortality rates and the percentage of infants who die in their first year of life. They also publish the proportionate infant mortality, that is, the per cents which the infant deaths are of the total deaths. It is interesting to compare these figures.

TABLE 107

INFANT DEATHS, HAMBURG

Year.	Proportionate mortality.	Infant mortality (per 1000 births.)	Number of infants per 1000 who died in their first year.
(1)	(2)	(3)	(4)
1908	26 2	156	184
1909	23 7	142	159
1910	24 4	149	160
1911	23 4	158	159
1912	20.8	130	141

This method of studying infant mortality by determining the percentage of first-year deaths was used in the Johnstown, Pa., investigation in 1914. It was here referred to as the "absolute infant mortality," the conventional method of comparing births and infant deaths for a calendar year being regarded, as indeed it is, as an approximate method, chosen for convenience only. In Johnstown the results were obtained by an intensive study of individual infants. Contrary to the results in Hamburg the "percentage of first-year deaths" was less than the "infant mortality," the figures being 13.4 per cent (134 per 1000) and 165 respectively.

Various methods of stating infant mortality. — It will be seen that infant mortality may be expressed in various ways:

1. Rate of deaths in first year — the true, or "absolute," method.
2. Infant mortality, the calendar ratio between infant deaths and births — the common method.
3. Specific death-rate for age-group 0–1 year — difficult to compute, but useful as hereafter shown.
4. Proportionate mortality — the ratio between infant deaths and total deaths.
5. Infant death-rate per 1000 inhabitants — a ratio rarely used and of little value.

It should be noticed that all of these ratios except the first are calendar ratios, that is, they are based on one year or some other interval of time. The true rate of infant deaths considers the calendar only as to births, the period covered by the deaths being one year from the date of each birth. In the following paragraphs all of these ratios are used in order that the student may learn to discriminate between them.

Chronological reduction in infant mortality. — The infant mortality rates in nearly all civilized countries are falling. In recent years the fall has been more rapid than it was a generation ago. In Sweden we have a very long record, a part of which is given in Table 108. Prior to 1800 the infant

TABLE 108

INFANT AND CHILD MORTALITY IN SWEDEN

1751 to 1900 by 5-Year Periods

Period.	Total death-rate per 1000	Age-group in years.			
		0–1.[1]	1–3.[2]	3–5[2]	0–5.[2]
(1)	(2)	(3)	(4)	(5)	(6)
1751–55	26 52	205 75	52 17	27 31	86 07
1756–60	28 25	203 41	49 50	26 26	81 64
1761–65	29 08	221 73	53 94	28 49	90 46
1766–70	26 38	210 41	50 12	27 06	85 14
1771–75	33 07	212 89	66 55	36 15	92 88
1776–80	24 36	192 02	56 21	29.13	83 74
1781–85	27 80	193 98	62 64	36 16	86 44
1786–90	27 61	205 70	48 78	23 04	81 67
1791–95	25 21	192 59	44 63	20 76	77 09
1796–00	25 65	199 53	48 02	23 47	79.55
1801–05	24 35	186 08	41 48	18 70	70 65
1806–10	31 45	211 46	59 09	29.09	87 42
1811–15	27 11	191 76	56 46	20.57	81 54
1816–20	24 63	175 51	45 93	17 96	71 00
1821–25	22 07	158 85	36 24	14 33	61 63
1826–30	25 10	175 76	37 72	17 07	64 53
1831–35	23 05	167 31	33 44	14 44	60.32
1836–40	22 53	166 35	35 47	15 42	60 31
1841–45	20 20	153 77	30 38	14 39	56.18
1846–50	20 95	152 56	33 39	16 48	57 34
1851–55	21 65	148 89	35 32	18 79	58.83
1856–60	21 73	143 47	39.12	23 87	61 96
1861–65	19 76	136 17	40 95	21 78	58 48
1866–70	20 54	141 93	38 78	19.59	56.14
1871–75	18 28	133 57	29 78	14 64	51.47
1876–80	18.26	126 28	36 26	19 80	53 01
1881–85	17.53	116 08	31 82	17.09	47 18
1886–90	16 37	105 00	25 88	13.41	40.06
1891–95	16 61	102 76	23 97	12 65	38.21
1896–00	16 12	100.50	21 78	9 72	35.65

[1] Per 1000 births during the given period, *i.e.*, "infant mortality."
[2] Per 1000 of population at middle of period, *i.e.*, specific death-rates.

mortality was upwards of 200, but by 1900 it was only about half as much. In Stockholm in 1912 it was only 82.

In Massachusetts[1] the rate of infant mortality has varied as follows:

TABLE 109

RATE OF DEATHS DURING FIRST YEAR

Massachusetts

Year	Per 1000.	Year.	Per 1000.	Year.	Per 1000.	Year.	Per 1000.	Year.	Per 1000.
(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
1851	133	1865	147	1879	145	1893	164	1907	133
1852	126	1866	138	1880	163	1894	163	1908	134
1853	135	1867	136	1881	163	1895	156	1909	127
1854	131	1868	140	1882	163	1896	158	1910	133
1855	135	1869	149	1883	159	1897	147	1911	119
1856	123	1870	162	1884	159	1898	151	1912	117
1857	118	1871	151	1885	157	1899	150	1913	110
1858	122	1872	194	1886	155	1900	157	1914	106
1859	130	1873	178	1887	160	1901	138	1915	102
1860	134	1874	164	1888	162	1902	140	1916	100
1861	146	1875	175	1889	160	1903	138	1917	97
1862	131	1876	158	1890	167	1904	133	1918	113
1863	150	1877	152	1891	162	1905	140	1919	89
1864	154	1878	150	1892	162	1906	138	1920	91

These figures when plotted on semi-log paper (Fig. 75) show three distinct periods, — a period of increase from 1851 to 1872, coincident with industrial development and foreign immigration; a period of gradual decrease from 1872 to about 1905; and a period of more rapid decrease since 1906, broken in 1918 by the influenza pandemic. If the rate of decrease since 1906 should continue the infant mortality will fall to 64 by the year 1930. The more rapid decrease in recent years is coincident with improvements in the milk supply.

The following figures show the decrease in infant mortality

[1] Mass. Registration Report, 1915, p. 153.

computed in the conventional way between 1908 and 1915 for Massachusetts, Boston and the remainder of the state outside of Boston.

TABLE 110

INFANT MORTALITY: MASSACHUSETTS

Year.	Massachusetts.	Boston.	Remainder of state.
(1)	(2)	(3)	(4)
1908	134	149	129
1909	127	121	129
1910	133	127	134
1911	119	126	118
1912	117	117	116
1913	110	110	110
1914	106	105	107
1915	102	104	101
1920	91	100	89

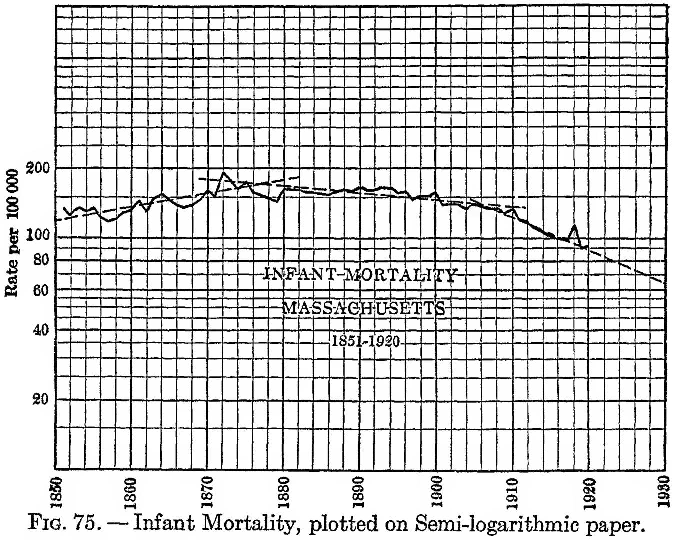


FIG. 75. — Infant Mortality, plotted on Semi-logarithmic paper.

This ratio is one which depends upon the number of children born as well as upon their rate of death, and involves the varying composition of the population as to age, marriage, nationality, and so on.

Reasons for the decreasing infant mortality. — As most of the current discussions of infant deaths are based on the calendar ratio between *reported* deaths of infants and *reported* births, it is well to remember that a falling ratio may result from an increase in the denominator as well as from a decrease in the numerator of the fraction. We have already learned that the birth registration is increasing in accuracy, that a larger percentage of births are reported now than formerly. This fact alone will account for a part of the drop in infant mortality; in some places it may account for nearly all of it. In comparing the infant mortality rates in different places this difference in the relative accuracy of reports of births and deaths must not be overlooked. To understand just what is being accomplished by present-day activities in infant welfare it is necessary to dig deeper into the subject and to analyze the statistics of infant births and deaths.

Infant mortality in different places. — If we examine the statistics for different countries we shall discover great differences in infant mortality. We have space here for only a few figures.

It would be possible to print page after page of such figures as these taken from the records of our American cities.

In Boston the rate of infant deaths per 1000 of total population has decreased as follows:

TABLE 111
INFANT MORTALITY: BOSTON

Year.	Rate per 1000 of population.	Year.	Rate per 1000 of population.
(1)	(2)	(1)	(2)
1875	6 6	1900	4 3
1880	5.6	1905	3.7
1885	5.5	1910	3.3
1890	5 1	1920	2.6
1895	5 1		

TABLE 112

INFANT MORTALITY IN A FEW FOREIGN CITIES

Cities.	1881–1885	1886–1890.	1891–1895.	1896–1900.	1901–1905.	1906–1910	1911.	1912.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
London	150	153	156	162	139	114	129	91
Edinburgh	127	136	140	144	131	119	118	113
Dublin (registration area)	176	175	169	175	158	146	156	140
Sydney	173	155	138	130	107	85	71	76
Melbourne	171	173	136	129	113	94	78	90
Montreal	..	246	237	258	271	261	242	.
Toronto	..	..	200	231	205	166	114	..
Paris	162	152	135	119	110	106	118	103
Amsterdam	203	199	168	146	122	90	91	64
Rotterdam	209	207	191	167	144	105	103	79
Stockholm	208	182	170	169	136	103	77	82
Christiania	156	168	158	152	119	96	116	107
St. Petersburg	301	243	242	251	246	256	231	249
Moscow	340	320	316	286	262	313	321	333
Berlin	279	264	242	218	202	164	173	142
Hamburg	222	260	226	182	174	150	158	130
Vienna	196	196	219	195	178	172	166	149
Prague	218	200	194	170	163	156	186	139
Budapest	244	237	199	174	149	151	161	141
Trieste	212	238	233	218	201	213	215	184
Milan	156	161	158	147	146	129	?	102
Buenos Aires	185	209	151	120	93	100	105	96

If we take the different cities of the United States we shall find ranges of infant mortality almost as great as in the cities of different countries. In 1915 the New York Milk Committee made an extensive study of the infant mortality rates of 144 United States cities. The minimum, median and maximum rates for the year 1915 were as follows:

TABLE 113

INFANT MORTALITIES IN UNITED STATES CITIES

Population group	Number of cities	Infant mortality		
		Minimum.	Median.	Maximum.
(1)	(2)	(3)	(4)	(5)
500,000–	10	82	104	120
200,000–500,000	20	53	84	133
100,000–200,000	16	47	100	182
50,000–100,000	31	62	98	193
30,000– 50,000	31	31	86	185
20,000– 30,000	21	37	98	167

These figures indicate that there was little difference in the median infant mortality between the large and the small cities, but that in the larger cities there was a greater uniformity in the figures. The very low rates as well as the very high rates were found in relatively small cities. The inaccuracies of the birth registration may account for many of these differences.

We may go even further and take the different wards of a single city, and find these same differences. In the twenty-five wards of Boston in 1910 the infant mortalities ranged from 75 to 210, the median being 117 and the average 122. In eleven districts of Johnstown in 1911 the "absolute infant mortality" varied from 50 to 271, the figure for the entire city being 134. And in the same way we could find differences block by block. In any intensive study it is of fundamental importance to find out the geographical location of infant deaths.

Infant mortality and climate. — Dr. F. S. Crum, in an important contribution to the American Journal of Public Health, has pointed out an important relation between climate and infant mortality. In those sections of the country where there are great extremes of heat and cold and much changeable weather the infant mortality is higher than in sections where the climate is more equible throughout the year and the weather changes less severe. For example, the infant mortality is much less in the Western Cities than in the cities of New England.

Deaths of infants at different ages. — A year is a long time in the life of an infant. One can learn no more from a study of the infant mortality, when all ages up to one year are considered together, than from a study of the general death-rate of a community where all deaths from zero to a hundred years of age are considered together. It is necessary to study the infant death-rate by months, weeks and even days.

The need of such study is obvious. During early life many of the deaths are from troubles incident to birth; later the question of feeding, and especially of the effect of artificial food becomes important. Some of the welfare activities are directed towards one end, some towards another. The establishment of milk stations, for example, might affect the death of weaned babies, but have little influence on babies less than a month old. There are many things which will occur to the reader which will show the importance of this specific information.

Let us first consider some of these subdivisions. In doing so, we may use several of the methods with which we have already become familiar.

In Hamburg, in 1912, the percentage age distribution of infant deaths was as follows:

TABLE 114

INFANT DEATHS AT DIFFERENT AGES: HAMBURG

Age-group, months.	Per cent of infant deaths in group.	Age, months.	Per cent of infants who died at less than age stated in column 3.
(1)	(2)	(3)	(4)
0+	38.5	1	38.5
1+	12.3	2	50.8
2+	9.8	3	60.6
3+	8.4	4	69.0
4+	6.1	5	75.1
5+	4.7	6	79.8
6+	4.3	7	84.1
7+	4.4	8	88.5
8+	3.0	9	91.5
9+	2.9	10	94.4
10+	2.6	11	97.0
11+	3.0	12	100.0

An irregular grouping is more common, because of the greater importance of the subdivisions at the very early ages. Thus for Boston, in 1912, we find the following figures:

TABLE 115

AGE DISTRIBUTION OF INFANT DEATHS: BOSTON, 1912

Age-group.	Per cent of infant deaths.		Age.	Per cent of infants who died at less than stated age.	
	Male	Female.		Male.	Female.
(1)	(2)	(3)	(4)	(5)	(6)
0– days	15.4	11.2	1 day	15.4	11.2
1+ days	4.0	4.5	2 days	19.4	15.7
2+ days	3.9	2.4	3 days	23.3	18.1
3+ days	6.8	7.7	1 week	30.1	25.8
1+ weeks	3.7	4.9	2 weeks	33.8	30.7
2+ weeks	5.4	4.4	3 weeks	39.2	35.1
3+ weeks	2.8	2.5	1 month	42.0	37.6
1+ months	10.9	9.0	2 months	52.9	46.6
2+ months	7.0	9.5	3 months	59.9	56.1
3+ months	18.1	19.2	6 months	78.0	75.3
6+ months	13.4	13.6	9 months	91.4	88.9
9 to 1 year	8.6	11.1	1 year	100.0	100.0
0 to 1 year	100.0	100.0			

It will be noticed that on the bases of the summation results of the last column the figures may be readily compared with those for Hamburg where the figures are given by regular monthly groups.

The important fact is that the death-rate of infants is much higher during the first weeks and days of life than it is after the first six months. The apparent increase from the eleventh to the twelfth month, often found, is very likely due to inaccuracies in stating the age at one year — the error of round numbers. Another method of studying this matter is to distribute the infant deaths by days through the first year of life. In Boston there were 1818 deaths during the year 1919, distributed as follows:

TABLE 116

AGE DISTRIBUTION OF INFANT DEATHS

Age-group (1)	Number of deaths in group	Number of deaths per day.
1 day	293	293
2–3 "	65	32.5
3–7 "	121	30 25
1–2 weeks	122	17.5
2–3 "	69	9.8
3–4 "	69	9 8
1–2 months	156	5.2
2–3 "	131	4 2
3–6 "	278	3 0
6–9 "	206	2.2
9–12 "	201	2 2

Specific death-rates of infants at different ages. — A better appreciation of the early infant mortality can be obtained by studying the specific death-rates of infants at different ages. In Glover's United States Life Tables we find the following figures which give the *monthly* specific death-rates.

TABLE 117

SPECIFIC DEATH-RATES OF INFANTS BY MONTHS, 1910

Original Registration States as Constituted in 1900

Age interval, months	Number dying in age interval among 1000 alive at beginning of age interval.	
	Males.	Females.
(1)	(2)	(3)
0 – 1	48 94	38 33
1 +	13 17	10 44
2 +	10 91	9 01
3 +	9 29	7 82
4 +	8 21	6.96
5 +	7 41	6 36
6 +	6 76	5 90
7 +	6 25	5 47
8 +	5 81	5 09
9 +	5 40	4 74
10 +	5 03	4 39
11 +	4 70	4 04
0 – 1 yr.	124 95	103 77

Expectation of life at different ages. — The expectation of life is given for infants as follows:

TABLE 118

EXPECTATION OF LIFE[1]

Original Registration States as Constituted in 1900

Age interval, months.	Average length of life remaining to each one alive at beginning of age interval. Years.	
	Males.	Females.
(1)	(2)	(3)
0 – 1	49 86	53 24
1 +	52 35	55 28
2 +	52 96	55 78
3 +	53.46	56 20
4 +	53 88	56 56
5 +	54 24	56.87
6 +	54 56	57.15
7 +	54.85	57.41
8 +	55 11	57.64
9 +	55 35	57 85
10 +	55 57	58.05
11 +	55.76	58 22

[1] Based upon deaths in 1909, 1910 and 1911.

The expectation of life of a male child at birth is about the same as that of a 11-year old boy. The expectation of life increases from birth to about the third year when it reaches its maximum.

Infant mortality by age periods. — Another way of showing the infant mortality by age periods is to find the ratios between the numbers of deaths in each period and the total number of births. These results may also be expressed cumulatively. Thus for Boston, in 1910, we have:

TABLE 119

INFANT MORTALITY, BOSTON, 1910

Age period.	Deaths per 1000 births.	Age period.	Deaths per 1000 births.
(1)	(2)	(1)	(2)
0-2 days	20	0-2 days	20
2 days-1 week	12	0-1 week	32
1 week-1 month	16	0-1 month	48
1-3 months	21	0-3 months	69
3-6 months	21	0-6 months	90
6-9 months	17	0- 9 months	107
9-12 months	15	0-1 year	122

Seasonal distribution of infant deaths by ages. — In Boston in 1919 the deaths of infants during their first two days of life were quite uniform throughout the year. From two days to thirty days of age there were many more deaths during cold weather than warm weather. From one month to six months the distribution was again fairly constant through the year, but after six months there were two maxima one in the winter and one in the summer.

Causes of infant deaths. — In Boston, in 1910, the principal causes of infant deaths were as follows:

TABLE 120

CAUSES OF INFANT DEATHS, BOSTON, MASS.

	Number of deaths.	
	Male.	Female.
(1)	(2)	(3)
I. General diseases, total	**113**	**100**
Measles	16	12
Diptheria and croup	18	8
Whooping cough	8	16
Erysipelas	10	8
Tubercular meningitis	15	14
Syphilis	11	12
II. Diseases of the nervous system, total	**47**	**47**
Meningitis	21	20
Convulsions	18	16
III. Diseases of the circulatory system, total	**4**	**4**
IV. Diseases of the respiratory system	**209**	**161**
Acute bronchitis	37	30
Broncho-pneumonia	88	71
Pneumonia	79	56
V. Diseases of the digestive system, totals	**355**	**270**
Diseases of stomach, except cancer	25	12
Diarrhea and enteritis	320	245
VI. Diseases of genito-urinary system	**2**	**6**
VIII. Diseases of skin and cellular tissue.	**8**	**2**
IX. Diseases of bones, etc.	**2**	**5**
X. Malformations	**69**	**51**
XI. Early infancy	**392**	**319**
Congenital debility	302	238
XIII. External causes	**9**	**7**
XIV. Ill-defined diseases	**35**	**32**
Total from all causes	**1245**	**1004**

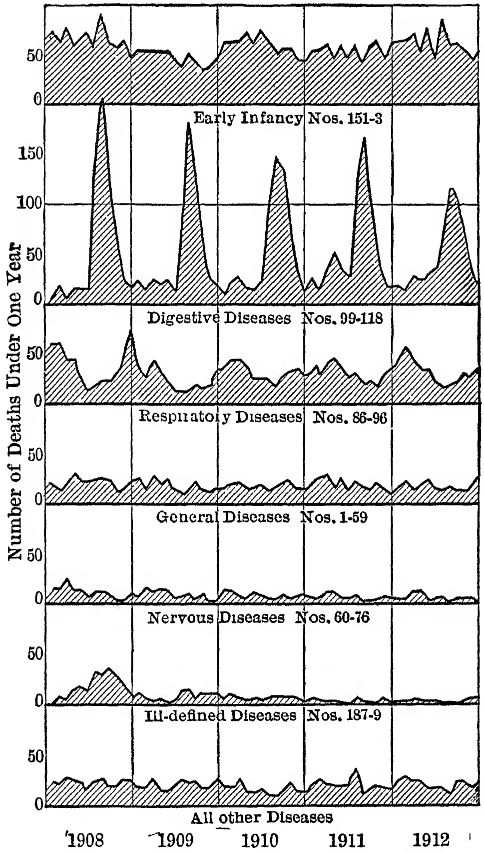


FIG. 76. — Infant Mortality by Months, Classified According to Cause: Boston, Mass.

Among both male and female infants 37 per cent of the deaths were from malformations and diseases of early infancy; about 27 per cent were from digestive diseases; about 17 per cent were from respiratory diseases. Together the deaths from these causes amounted to four-fifths of all the infant deaths. These percentages are not constant. There is an important seasonal variation; there are also differences according to age and nationality.

In 1912, Dr. Wm. H. Davis made an excellent analysis of the infant deaths in Boston for a five-year period. Fig. 76, drawn from figures in his report, shows how the deaths from digestive diseases have fallen during the summer season, but remained almost unchanged during the winter; how the deaths from respiratory diseases are higher in the winter than in the summer; and how the deaths from diseases of early infancy, the general diseases and nervous diseases do not have a marked seasonal distribution. The diagram also shows how the diseases from ill-defined causes have decreased, due, it is said, to better diagnosis.

In Boston the diseases were classified by cause and age as follows:

TABLE 121

CAUSES OF INFANT DEATHS: BOSTON, 1910

Cause	Number of deaths.							
	0–1 Days.	2–6 Days.	1–30 Days.	1–2 Months.	3–5 Months.	6-8 Months.	9–11 Months.	Total Infant.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
I. General disease	0	2	21	37	43	58	52	213
II. Nervous system	1	8	6	17	17	24	21	94
III. Circulatory system	0	1	2	4	1	0	0	8
IV. Respiratory system	1	9	54	68	80	89	69	370
V. Digestive system	0	10	41	153	201	112	108	625
VI. Genito-urinary system	0	0	0	1	2	2	3	8
VIII. Skin and tissue	0	0	3	0	3	2	2	10
IX. Bones	0	0	0	0	2	3	2	7
X. Malformations	41	32	24	11	7	3	2	120
XI. Early infancy	305	147	135	99	12	8	5	711
XIII. External causes	5	0	2	3	4	1	1	16
XIV. Ill-defined causes	0	4	3	7	33	15	5	67
All causes	353	213	292	400	405	317	270	2249

As would be expected from the definition the largest numbers of deaths from causes incident to early infancy occur among early infants. This is true also of malformations. The intestinal diseases reach their maximum effect between the third and fifth month, the respiratory diseases and the general diseases, which are chiefly communicable, a little later — say between the sixth and eighth months.

In Johnstown important differences were noted between the causes of death among infants of native and foreign mothers. Thus, during the first year of life the following absolute infant mortalities, with subdivisions by cause were found.

TABLE 122

CAUSES OF INFANT DEATHS: JOHNSTOWN

	Native mothers	Foreign mothers
(1)	(2)	(3)
All causes	104	171
Diarrhœa and enteritis	21	54
Respiratory diseases	23	48
Premature births	14	20
Congenital debility or malformations	6	21
Injuries at birth	7	2
Other cause, or not reported	33	26

In Boston the following figures were given for 1910 for deaths of infants born to native and foreign mothers:

TABLE 123

CAUSES OF INFANT DEATHS: BOSTON

	Rates per 1000 births				
	Native mothers.	Canadian mothers	Irish mothers.	Italian mothers.	Russian mothers.
(1)	(2)	(3)	(4)	(5)	(6)
Congenital debility and malformations	50	31	49	24	20
Diarrhœa and enteritis	34	37	43	22	19
Pneumonia and broncho-pneumonia	15	18	12	29	16
Diseases of early infancy	10	13	16	4	7
Tuberculosis	2	4	1	2	2
Measles, scarlet fever, whooping cough and diphtheria	3	3	3	8	4

The Johnstown studies. — In 1915 the Children's Bureau of the U. S. Department of Labor,[1] published an important intensive study of the Infant Mortality of Johnstown, an industrial city of Pennsylvania. Miss Julia C. Lathrop is the Chief of this bureau. The field work was in charge of Miss Emma Duke. This was essentially a sociological study. Only a few of the simple correlations can here be presented. The report is one which the student may profitably read in full.

TABLE 124

INFANT MORTALITY AND TYPE OF HOME

Housing condition	Infant mortality.
(1)	(2)
Clean, dry.	105
" damp	127
Moderately clean, dry	171
" " damp	158
Dirty, dry	162
" damp	204
Water supply in house	118
Water supply outside	198
Water closet	108
Yard privy	159

[1] Infant Mortality Series No. 3.

TABLE 125

INFANT MORTALITY AND SLEEPING ROOMS

	Infant mortality.
(1)	(2)
Number of others sleeping in same room with baby:	
2 or less	67
3 to 5	98
Over 5	123
Baby sleeping in separate bed:	
Yes	56
No	109

TABLE 126

INFANT MORTALITY AND VENTILATION

Ventilation of baby's room.	Infant mortality.
(1)	(2)
Good	28
Fair	92
Poor	169

TABLE 127

INFANT MORTALITY AND ATTENDANT AT BIRTH

	Infant mortality.
(1)	(2)
Physician	100
Midwife	180

TABLE 128

INFANT MORTALITY AND EDUCATION OF FOREIGN MOTHERS

	Infant mortality.
(1)	(2)
Literate	148
Illiterate	214
Speak English	146
Do not speak English	187

TABLE 129

INFANT MORTALITY AND AGE OF MOTHER

Age of mothers.	Infant mortality.
(1)	(2)
Under 20	137
20–24	121
25–29	143
30–39	136
40 and over	149

The study of feeding was made by months. The following figures show the rate of mortality per 1000 babies alive at the specified time.

TABLE 130

INFANT MORTALITY AND FEEDING

Age at which the stated type of feeding was found.	Specific infant mortality (absolute)		
	Breast feeding only.	Mixed feeding.	Artificial feeding only.
(1)	(2)	(3)	(4)
Second month.	72	78	237
Third "	54	92	217
Fourth "	47	57	166
Fifth "	38	40	127
Sixth "	26	32	92
Seventh "	29	22	72
Eighth "	26	20	53
Ninth "	18	16	25
Tenth "	14	11	11

In the early ages the difference between deaths of breast-fed infants and those artificially fed is very great, but the difference becomes less as the baby grows older.

TABLE 131

INFANT MORTALITY AND HOUSEHOLD DUTIES

Household duty	Infant mortality.
(1)	(2)
Cessation of duties before confinement:	
None or less than one month.	137
One or more months.	113
Time of resuming all household duties after confinement:	
8 days or less.	169
9 to 13 days.	165
14 days or more.	117

TABLE 132

INFANT MORTALITY AND EARNINGS OF FATHER

Annual earnings of husband	Infant mortality.	
	Native wives.	Foreign wives
(1)	(2)	(3)
Under $521	....	251
$521 to $624	146	162
$625 to $779	70	130
$780 to $899	131	167
$900 to $1199	76	152
$1200 or more	....	....
Ample	78	108

The report also contains statistics relating to reproductive histories of the mothers studied during the investigation.

Data of this sort, while of interest and of value, must be used with great caution for the reasons set forth in Chap. VII.

Other studies of the Children's Bureau. — Besides the Johnstown studies, here emphasized because they were first made, the Children's Bureau has made at this writing (1918), intensive studies in Manchester, N. H., Saginaw, Mich., Waterbury, Conn., Brockton and New Bedford, Mass., Akron, Ohio, and Baltimore. A brief account of these most important intensive investigations, based on a first-hand collection of the facts may be found in the Quarterly Publication of the American Statistical Association.[1]

Two tables from this report are of interest:

[1] Robert M. Woodbury, Infant Mortality Studies of the Children's Bureau, June 1918, pp. 30–53.

TABLE 133

INFANT MORTALITY AND FATHER'S EARNINGS, BALTIMORE

Earnings of father per year.	True infant mortality rate.	Earnings of father per year.	True infant mortality rate.
(1)	(2)	(1)	(2)
No earnings	207.7	$1050–1249	66 6
Under $450	156 7	1250–1449	74 0
$450–$549	118.0	1450–1849	86 3
550– 649	108 8	1850 and more	37.2
650– 849	96 06	Not reported	140 2
850–1049	71 5	All classes	103 5

TABLE 134

INFANT MORTALITY AND ORDER OF BIRTH—MOTHERS OF ALL AGES

Number of birth in order.	True infant mortality.	Number of birth in order.	True infant mortality.
(1)	(2)	(1)	(2)
1	115 8	7	128 2
2	102 7	8	162.6
3	111 5	9	142.1
4	127 0	10	181.1
5	129 3	11	146.8
6	132 2		

Although in general the average infant mortality is less for the second child than for the first or subsequent children, this is a matter which varies somewhat with the age of the mother. For mothers under twenty the mortality is lowest for first children; for mothers aged 30–34 years it is lowest for the third children; and for mothers aged 35–39 it is lowest for fourth children. Perhaps, if nationality were considered, other differences would be noticed.

Infant mortality problems. — There are many practical problems relating to infant mortality which must be studied with the aid of statistics. The object of the tables here given is to show the complexity of the problem and the futility of depending alone upon the current approximate method of stating infant mortality. Extensive compilations of data for various places and for different years make easy reading and give one a superficial knowledge of the subject, but they do not help us very much in solving real problems. It is the intensive studies which count. What kind of welfare work deserves the largest appropriations? The answer depends upon where the babies are dying, at what age they are dying, under what social conditions, under what remediable conditions, and so on. Are the milk stations of our large cities a paying life-saving agency? The answer cannot be told by comparing the conventional infant mortality rates; perhaps the reduction of infant mortality may be among the earliest weeks of life, an age at which artificial feeding is less common. What relation is there between density of population and infant mortality? The answer cannot be found without splitting up the infant mortality into its constituent parts.

The lesson is one which the author wishes to teach in every chapter of this book, namely, that the vital statistician must train himself to analyze his statistics; to be specific; to think first what kind of facts he needs in order to answer a specific question and then go after them, remembering that a small number of well-directed statistics are worth more than vast numbers of general statistics, piled together without regard to internal differences which may make them worthless.

Maternal mortality. — Closely associated with infant mortality we have the problem of maternal mortality. Since the long-ago studies of Dr. Oliver Wendell Holmes, but especially since the rise of bacteriology, there has been a very great decrease in death-rates from child-bed fever, but even within very recent years we can see an added improvement, which can be attributed to the general attention being given to pre-natal care, to laws in regard to mid-wives and similar causes. The following condensed figures for New York city[1] illustrate this decrease.

TABLE 135

MATERNAL MORTALITY-RATE, CITY OF NEW YORK

Quinquennial period	Rate per 100,000 females (age 15–45).	
	Puerperal sepsis.	Other puerperal causes
(1)	(2)	(3)
1898–1902	25 9	40 5
1903–1907	26 1	41 3
1908–1912	18 3	35 7
1913–1917	15 3	29 8

These figures might more properly have been based on married women within the given ages, or upon births and still-births taken together instead of on all females of child-bearing age, but the chronological differences are so great as to leave no room for doubt as to the main facts.

Childhood mortality. — The period of life between the ages of one and five years represents a peculiar environment which may be described by the words home and play. In this period the physiological influence of the mother on the child becomes less, but her intelligence, her social and economic condition, the general environment of the house and the neighborhood become greater. During these four years the specific death-rate of children decreases greatly and the diseases to which they are subject change in character.

[1] Weekly Bulletin, Dept. of Health, March, 1918.

TABLE 136

SPECIFIC DEATH-RATES OF CHILDREN[1]

U. S. Registration Area, 1910–1915

Age	Rate per 1000	
	Male.	Female.
(1)	(2)	(3)
0 – 1 year	125 8	101 1
1 +	27 3	25.0
2 +	11 0	10 1
3 +	6 9	6 3
4 +	5 1	4.7
0–5 years	36 0	30 0
5–9	3 3	3 0
10–14	2 3	2.1

[1] From Dr. Dublin's paper.

The diseases which occur during childhood are especially amenable to preventive measures, a fact which makes their study one of especial importance from the standpoint of life saving.

Diseases of early childhood. — Dr. Louis I. Dublin, Statistician of the Metropolitan Life Insurance Company has discussed these diseases in an article on the Mortality of Childhood,[1] from which the figures for proportionate mortality given in Table 137 are taken.

This table gives only those diseases for which the proportionate mortality was more than 3 per cent of all deaths. One rather unexpected cause of death looms large in this table — namely, burns. In the second year of life the proportionate mortality was 1.7 per cent, the next year 4.3 per cent, the next 5.9 per cent, the next 5.7 per cent. Dr.

[1] Quarterly Publications, Am. Statistical Assoc., March, 1918, p. 921.

TABLE 137
PROPORTIONATE MORTALITY, AGES 1 TO 5
U. S. Registration Area 1910–15

Age 0–1.	Per cent.	Age 1–2	Per cent.	Age 2–3	Per cent.	Age 3–4	Per cent.	Age 4–5	Per cent.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Congenital debility.	25.9	Diarrhœa and enteritis	27.3	Diarrhœa and enteritis	13.2	Diphtheria	17.0	Diphtheria	18.8
Diarrhœa and enteritis.	24.4	Broncho-pneumonia	14.4	Diphtheria	12.2	Broncho-pneumonia	7.8	Scarlet fever	7.6
Broncho-pneumonia	8.1	Pneumonia	9.5	Broncho-pneumonia	11.1	Pneumonia	7.6	Pneumonia	6.8
Diseases of early infancy	6.1	Diphtheria	5.8	Pneumonia	8.9	Diarrhœa and enteritis	7.3	Broncho-pneumonia	6.0
Malformations	5.6	Measles	5.9	Measles	5.5	Scarlet fever	7.0	Burns	5.7
		Whooping cough	4.6	Scarlet fever	4.7	Burns	5.9	Diarrhœa and enteritis	5.0
		Tuberculous meningitis	3.1	Burns	4.3	Measles	4.4	Tuberculous meningitis	3.8
				Whooping cough	4.0	Tuberculous meningitis	4.0	Measles	3.5
				Tuberculous meningitis	3.9	Whooping cough	3.2		

Dublin in the paper referred to gives the specific death-rates as well as the proportionate mortalities. The figures for burns are for the second year 44.1 per 100,000, for the third, 44.8, for the fourth, 39.4, for the fifth, 28.1. The increasing importance of such communicable diseases as diphtheria, whooping cough, measles and the like during this period shows the increasing influence of environment and association of children with each other.

Proportionate mortalities during school age. — During the ages from 5 to 15 when children are at school we have what is perhaps the maximum opportunity for contact infection. During these ages, therefore, we may expect to see communicable diseases coming to the front in our proportionate mortalities. But we also find weaknesses in the human mechanism making themselves felt. Tuberculosis and typhoid fever also begin to loom up as great menaces.

TABLE 138

PROPORTIONATE MORTALITY

U. S. Registration Area, 1910–15

Ages 5–9.	Per cent.	Ages 10–14.	Per cent.
(1)	(2)	(3)	(4)
Diphtheria and croup	15 8	Tuberculosis of lungs	10.2
Scarlet fever	7 1	Organic diseases of heart	8.6
Pneumonia	5 9	Typhoid fever	6 4
Organic diseases of heart	4 4	Appendicitis	6 3
Vehicular accidents	4 4	Diphtheria	5.6
Typhoid fever	3 7	Pneumonia	5 3
Broncho-pneumonia	3 5	Drowning	4 4
Tuberculosis of lungs	3 5	Vehicular accidents	4.4
Appendicitis	3.4	Scarlet fever	3.0
Tuberculous meningitis	3 4	Acute-articular rheumatism	3.0
Burns	2 7		
Drowning	2 6		
Measles	2.5		

Proportionate mortalities at higher ages. — The following statistics show the proportionate mortalities for age-groups 30–34, 50–54 and 70–74 years.

TABLE 139

PROPORTIONATE MORTALITY

U. S. Registration Area, 1914, Males

Age 30–34 years	Per cent.	Age 50–54 years.	Per cent	Age 70–74 years	Per cent.
(1)	(2)	(3)	(4)	(5)	(6)
Tuberculosis	32.0	Tuberculosis	13.4	Organic diseases of heart	21.6
Accidents	16.1	Organic diseases of heart	11.7	Bright's disease	13.4
Pneumonia	6.9	Bright's disease	11.0	Apoplexy	12.8
Organic diseases of heart	5.4	Cancer	8.1	Cancer	8.4
Angina pectoris	5.2	Accidents	8.0	Pneumonia	4.9
Suicide	4.2	Pneumonia	7.7	Diseases of arteries	4.5
Bright's disease	4.1	Apoplexy	6.8	Accidents	3.2
Typhoid fever	2.8	Suicide	3.2	Tuberculosis	2.8
Homicide	2.8	Cirrhosis of liver	2.9	Old age	2.0
Appendicitis	1.9	Diabetes	1.7	Broncho-pneumonia	1.9
Cancer	1.6	Paralysis	1.5	Diseases of prostate	1.7
		Acute endocarditis	1.4	Paralysis	1.6
		Pleurisy	1.4	Cirrhosis of liver	1.5
		Alcoholism	1.2	Diabetes	1.5
				Angina pectoris	1.4
				Influenza	0.9

Tuberculosis stands at the head of the list until age 70. Organic diseases of the heart increase with age. Accidents diminish. Bright's disease increases. Suicide decreases. Cancer increases, and so on.

Of course in a complete study all of these diseases at different ages should be studied by the use of specific rates as well as proportionate mortality. Studies by sex, by season, by nationality, and so on, should also be made.

Average age of persons living. — The average age of a community is, of course, the weighted average of the different age-groups. It is the sum of the ages of all the people divided by the total population.

In 1880 the average age of the aggregate population of the U. S. registration area was 24.6 years, in 1890 it was 25.6, in 1900, 26.3 years. There has apparently been an increase although the figures do not stand for exactly the same areas. But this result might be due to a lessening of the birth-rate, to an increase in infant mortality, to an influx of immigrants of middle age or to a reduced death-rate among the aged. That the native birth-rate has been declining is true, that immigrants of middle age have been entering the country is also true. These would tend to increase the average age. But the infant mortality has been decreasing, not increasing, and the mortality in the higher age-groups has rather increased than diminished. These factors would tend to decrease the average age. Evidently the problem is so complicated that the average age of the living cannot be fairly taken as an index of hygienic conditions.

Median age of persons living. — Instead of finding the average age of the living the median might be used, but the objections to the average age of the living would apply also to the median, although the magnitude of their influence would be somewhat different. The median age of the population of the United States has greatly increased during the last century as the following figures show:

TABLE 140

MEDIAN AGE OF WHITE POPULATION: UNITED STATES

Year.	Median age
1800	16 0
1810	16 0
1820	16 5
1830	17 2
1840	17 9
1850	19 1
1860	19.7
1870	20 4
1880	21 3
1890	21 9
1900	23 4
1910	24 4

Average age at death. — Nor does the average age at death afford a fair index of the healthfulness and physical welfare of a community. The reasons are similar to those just mentioned. A high average age at death may mean simply that the birth-rate is low.

There has been, in recent years, a general rise in the average age at death. In Rhode Island, for example, the increase has been as follows:

TABLE 141

AVERAGE AGE AT DEATH: RHODE ISLAND

Period.	Average age at death.	Period.	Average age at death.
(1)	(2)	(3)	(4)
1861–65	29.32	1891–95	33 96
1866–70	32 42	1896–00	34 53
1871–75	30 16	1901–05	36.11
1876–80	31.21	1906–10	37 16
1881–85	33.99	1911–15	39.91
1886–90	33.42	1919–	41.22

In 1900 the average age at death in the registration states of the U. S. was 36.8 years. For the cities it was 32.4; for the rural districts 44.7 years. In Mass., in 1910, the average age at death was 39.51. In 1913 the average age at death for the U. S. Registration Area was 39.2 years for males, 40.6 years for females, and 39.8 years for the entire population.

A paragraph in a New York paper recently stated that in 153 years, the average age of life will be one hundred years. This was based on the rising average age of death. The computation was, of course, absurd.

In a general way, however, the prolongation of life may be regarded as an index of human progress, as Professor W. F. Willcox has pointed out.

EXERCISES AND QUESTIONS

1. Compare the infant mortalities for certain assigned large cities and rural districts.

2. Compare the infant mortalities for California cities with those of eastern cities.

3. Compute the seasonal variations of infant mortality for California cities.

4. What is the average infant mortality in New South Wales? Why is it so low?

5. Do the statistics of infant mortality justify the continuance of the milk stations in New York City?

6. In what direction will efforts to reduce infant mortality yield the most profitable results?

7. Is poverty, ignorance, race or climate the greatest factor in causing high infant mortalities?

8. Make a statistical study of some cause of death, to be assigned by the instructor, according to age periods.

CHAPTER XIII

PROBABILITY

In the second chapter it was shown that the average, or mean, of a number of figures gave a very inadequate idea of the figures themselves; that two sets of figures may have the same average yet differ among themselves in a striking manner. It is often important to find out what these differences, or *variations*, are. We have seen that one way to do this is to arrange the items in array, that is, in order of magnitude and find the median, the mode, the quartiles and so on, but even this is not enough; it is necessary, if possible, to find some mathematical relation between the variations.

Natural frequency. — It is a curious and important fact that if we measure natural objects, such as the lengths of the leaves on a tree, or the heights of a regiment of men, or the lengths and breadths of nuts, to use illustrations studied by the Eldertons in their Primer of Statistics, we shall find that most of the observations will be very close to the mean of all, that a few will differ from it considerably and that a very small number will differ from it very greatly. In a thousand observations a certain number are almost sure to differ from the mean by a definite amount, and a certain other number are almost sure to differ from the mean by twice that amount. In fact these relations are so regular as to amount to what may be called a law of nature, a sort of natural frequency. In these variations we shall find some observations larger than the mean and some smaller. Natural frequency can best be understood by an example.

Twenty students in a college class were placed in array in accordance with their height, with the result shown in Fig. 77. The marks of the same students at a certain

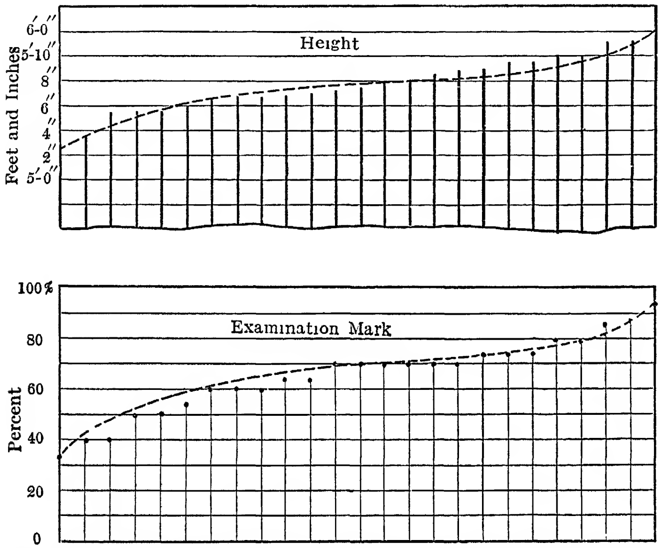


Fig. 77. — Array of heights of students and examination marks.

examination showed the same characteristic distribution, that is uniformity in the middle range and a tapering off at the extremes.

When the observations are too many to be placed in array it is necessary to group them. In a certain army the results of measurement of the heights of 18,780 soldiers were as follows:

TABLE 142

HEIGHTS OF SOLDIERS

Height in inches.	Number of soldiers in height-group.	Per cent of soldiers in height-group.	Number of soldiers less than height stated in column (1)	Per cent of soldiers less than height stated in column (1)
(1)	(2)	(3)	(4)	(5)
60 +	197	1.05	.....	......
61 +	317	1 69	197	1 05
62 +	692	3.69	514	2 74
63 +	1,289	6.86	1206	6.43
64 +	1,961	10.44	2495	13 29
65 +	2,613	13 91	4456	23 73
66 +	2,974	15.84	7069	37.64
67 +	3,017	16 07	10043	53 48
68 +	2,287	12.18	13060	69 55
69 +	1,599	8.52	15347	81.73
70 +	878	4.67	16946	90 25
71 +	520	2.77	17824	94.92
72 +	262	1.39	18344	97 69
73 +	174	0.92	18606	99 08
Total........	18,780	100 00	18,780	100 00

It will be seen that the *mode*, the most commonly observed height, was in height-group 67 +, *i.e.*, between 5 feet 7 inches and 5 feet 8 inches. The mean was 67.24 inches. If we should attempt to stand these 18,780 in array we should have an impossible task. We may do it statistically, however.

Fig. 78 shows the number of soldiers less than successive heights, plotted as a summation curve from Column (4), in Table 142, and Fig. 79 shows the same in percents, plotted from Column (5). The characteristic ogee curve will be observed in all these cases.

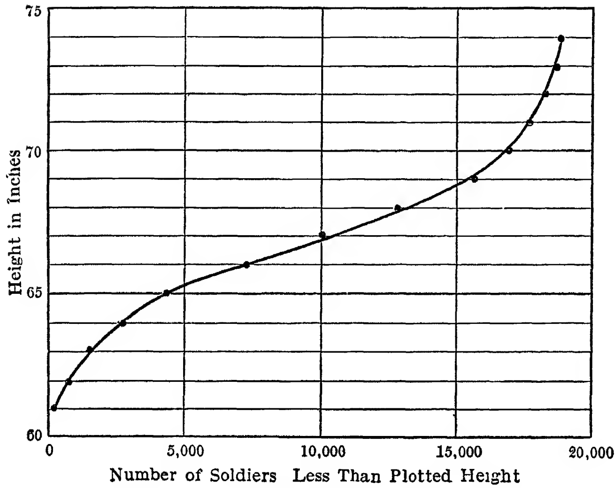

75
70
65
60
Height in Inches
0
5,000
10,000
15,000
20,000
Number of Soldiers Less Than Plotted Height

FIG. 78

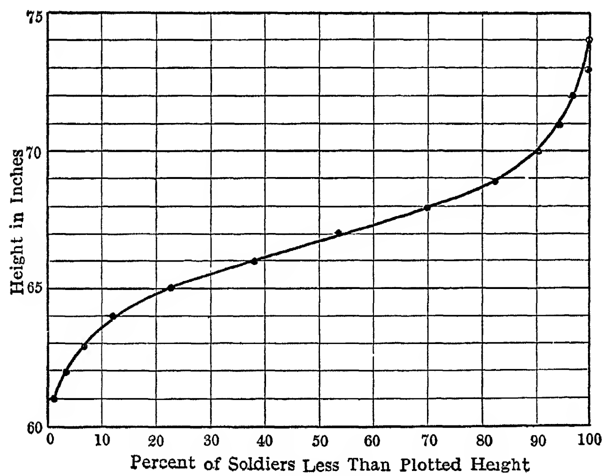

75
70
65
60
Height in Inches
0
10
20
30
40
50
60
70
80
90
100
Percent of Soldiers Less Than Plotted Height

FIG. 79

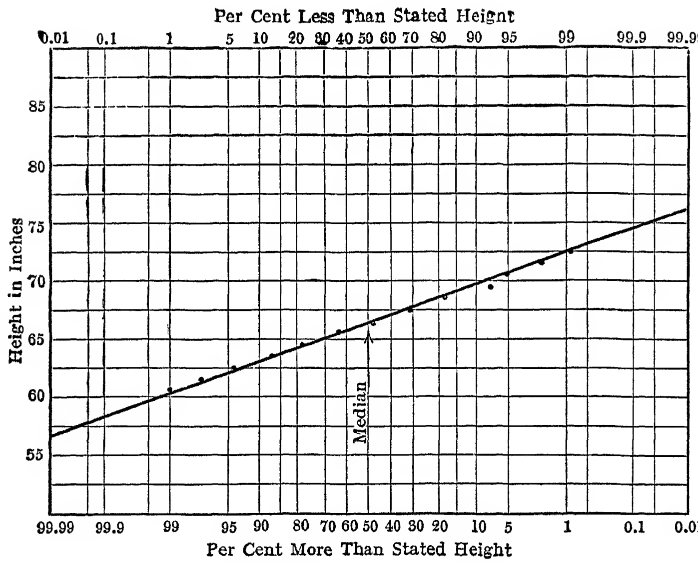


Fig. 80. — Heights of Soldiers, plotted on Probability Paper.

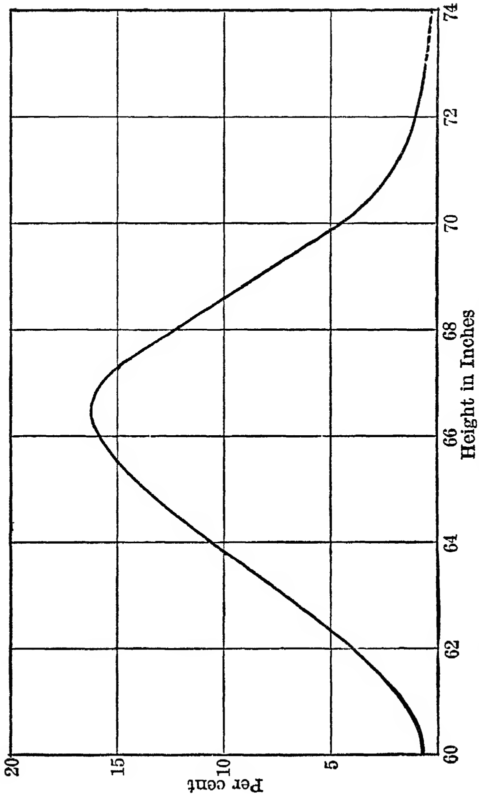


FIG. 81. — Percentage Distribution of Soldiers According to Height.

The *median* height can be easily determined from this curve. It is the height corresponding to 50 per cent, *i.e.*, to the middle man: By taking a weighted average as described in the second chapter the *mean* may be obtained from the data in the table.

Let us now look at the variations in height of these soldiers in a different way and plot the data by height groups, as in Fig. 81. This will give us a characteristic curve highest in the middle and sloping downwards gently towards either end. This is called a *frequency curve.* It should be noticed that whereas in the array the height was indicated by the vertical scale it is in this diagram indicated by the horizontal scale. This frequency curve, or curve of variation, plays a very important part in the statistical study of all natural phenomena.

Coin tossing. — Ten coins were tossed into the air by the students in a college class an aggregate of 1250 times, records being kept of the number of heads which came up. The results were as follows:

TABLE 143

RESULTS OF COIN TOSSING

Number of heads up at once	Number of throws	Number of heads up at once.	Number of throws.
(1)	(2)	(1)	(2)
0	1	6	266
1	15	7	128
2	62	8	55
3	156	9	13
4	265	10	1
5	288		

These results when plotted gave a frequency curve which was much like that obtained for the soldiers. This curve was evidently the result of chance. One cannot tell for any given throw how many heads will come up, yet in the long run one always gets such result as that obtained by the coin tossing students.

What is meant by "chance." — What determines whether a coin thrown into the air will fall with the head up? Many things, of course, — the way it is held when thrown, the twist with which it starts, the height to which it rises, the manner in which it strikes the floor, the way it rolls, and many other factors. The sum total of these many causes gives what we call "chance." Chance is not the absence of cause, it is the result of a multiplicity of causes. In chance we must judge the result by the combination of these many causes. Often it is the only way we can judge the result. In chance we can never tell exactly any particular result, but we can form an idea as to the frequency with which any possible result will occur.

In the case of the coins we could not tell in advance the result of any particular throw of ten coins but we could safely predict that five heads would be thrown more often than any other number, and that no heads or ten heads would happen least frequently. Is there any way by which the frequency that other numbers of heads would be thrown can be ascertained? There is, and it is quite simple.

We will start with a single coin. We toss it up. It is an even chance as to whether it comes up a head or a tail. If we should toss the coin a hundred times we would probably have a head in fifty of the throws. In practice it might not come out exactly 50, it might be 48 or 55, but if we tossed the coin an enormously large number of times a head would come up half the time. Let us now take two coins which we will call *a* and *b*. If we indicate a head by heavy type then we have the following possible combinations:

ab; **a**b; a**b**; ab.

We thus have the following results:

Heads	0	1	2	
Number of throws	1	2	1	Total 4

If we have three coins we have the following possible chances:

abc; **ab**c, **a**bc, a**bc**; **a**bc, a**b**c, ab**c**; abc.

Heads	0	1	2	3	
Number of throws	1	3	3	1	Total 8

If we have four coins we have:

abcd; **abc**d, **ab**c**d**, a**bcd**, **a**b**cd**; **ab**cd, **a**b**c**d, **a**bc**d**, a**bc**d, a**b**c**d**, ab**cd**; **a**bcd, a**b**cd, ab**c**d, abc**d**; abcd.

Heads	0	1	2	3	4	
Number of throws	1	4	6	4	1	Total 16

And so it goes on until for 10 coins we have:

Heads	0	1	2	3	4	5	6	7	8	9	10	
Number of throws	1	10	45	120	210	252	210	120	45	10	1	Total 1024

Theoretically, therefore, the coins in 1250 throws should have given us the following numbers: These compare reasonably well with those obtained by the students.

TABLE 144

THEORETICAL RESULT OF TOSSING 10 COINS 1250 TIMES

Number of heads.	Number of throws.	Number of heads.	Number of throws.
(1)	(2)	(1)	(2)
0	1	6	257
1	12	7	147
2	55	8	55
3	147	9	12
4	257	10	1
5	307		

Binomial theorem. — Another interesting fact is that these numbers which we have just obtained as representing what would result from applying the laws of chance to the tossing of two, three and more coins, are the same as are obtained by expanding the sum of two quantities by the binomial theorem, $(a + b)^n$ in which each quantity, a and b is taken as 1, *i.e.*, $(1 + 1)^n$. In the problem a head was just as likely to come up as a tail. In this expression n is the number of coins. If

$$n = 1, \quad (1 + 1)^1 = 1 + 1,$$
$$n = 2, \quad (1 + 1)^2 = 1 + 2 + 1,$$
$$n = 3, \quad (1 + 1)^3 = 1 + 3 + 3 + 1,$$
$$n = 4, \quad (1 + 1)^4 = 1 + 4 + 6 + 4 + 1,$$
$$n = 5, \quad (1 + 1)^5 = 1 + 5 + 10 + 10 + 5 + 1.$$

The binomial theorem, therefore, gives us a method of finding the shape of any natural frequency curve if we know the number of terms. It should be observed that only the even values of n give an odd number of terms with a middle highest term.

Some interesting conclusions may be predicted from this application of the binomial theorem. One of them is that the larger the number of terms the more closely are the items clustered around the median figure. It follows that the average of a large number of observations is much more precise than the average of only a few observations. In fact, it can be shown that the error of a set of observations varies inversely as the square root of the number of observations. If we multiply the number of observations by four, we halve the probable error.

Chance and natural phenomena. — Does it follow therefore that the measurements of natural phenomena result from chance? Certainly, if they follow the binomial law as pointed out. How is it in the case of the heights of soldiers?

Here we had 18,780 soldiers. Theoretically, these should have been distributed as shown in Column 3 of Table 145. Actually they were distributed as in Column 2. The differences are very slight.

What are the many causes which determine a person's height? It is difficult to say. Possibly inheritance, age, nationality, food supply during the period of growth, early illnesses, habits of sleeping, sitting, standing and many other factors. It would be an interesting subject for discussion. Whatever the causes are they are combined in so many ways that we have no better method of predicting the heights of the soldiers in a regiment than by the application of this law of chance.

TABLE 145

HEIGHTS OF SOLDIERS

Height in inches	Per cent of soldiers.	
	Actual.	Theoretical
(1)	(2)	(3)
60 +	1.05	1 00
61 +	1 69	1 71
62 +	3 69	3 68
63 +	6 86	6 75
64 +	10 44	10 51
65 +	13 91	13 99
66 +	15 84	15 84
67 +	16 07	15 31
68 +	12 18	12 60
69 +	8 52	8 84
70 +	4 67	5 31
71 +	2 77	2 67
72 +	1 39	1 18
73 +	0 92	0 61
	100 00%	100 00%

Skew curves. — In plotting natural phenomena it will be found that not all frequency curves are symmetrical. The median is not always the mean; there may be more items on one side of the mean than on the other. The asymmetrical curves are known as skew curves. They are not susceptible of mathematical analysis except by the use of complicated and rather uncertain methods.

There are four common types of asymmetrical curves commonly met with in demographic studies. These are shown in Fig. 82. In this diagram *A* represents the symmetrical frequency curves, the two sides of which are symmetrical about the mode. This type of curve has already been discussed. Type *B* is represented by the age distribution of deaths from measles. In early childhood the curve rises sharply. Type *C* is a variant of *B*. Type *D* starts off with the mode and steadily diminishes. Age distribution of infant deaths by months gives us an example of this curve. Type *E*, the U-shaped curve, is already familiar to us. It is substantially the curve of specific death-rates by ages. All of these skew curves take many forms.

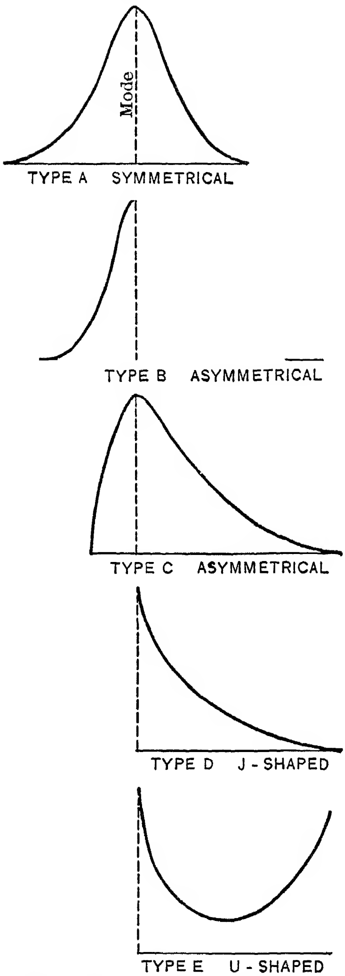


FIG. 82. — Types of Frequency Curves.

It will be remembered that in the case of the law of chance it was assumed that the chance of an event happening and of its not happening were equal. The chance of the coin falling as a head was the same as that of its falling as a tail, and one or the other was bound to happen. But we can imagine a result depending upon many factors, one of which was much more likely to occur than not to occur. This would result in producing a skew curve. There might be many such factors, and these might exist in all sorts of combinations.

When statistics naturally plot out as a skew curve it is a sign that they should be investigated to determine, if possible, what the influence is which is producing the skewness. Sometimes it can be found. For example, in a case recently studied the quantity of butter fats in a series of analyses of milk samples was slightly skewed at one end. This was found to be due to the adulteration of about five per cent of the samples with water.

Beyond recognizing the skewness of a curve and making some attempt to account for it, the student of vital statistics will do well to let the mathematics of skew curves alone. Karl Pearson and others of his school have suggested certain methods of mathematical analysis.

Deviation from the mean. — Still another way of studying variation is to find the extent to which the heights of the soldiers differed from the average, or mean, height. The mean height was 67.24″. For the sake of simplicity let us call it $67\frac{1}{4}''$. We may fairly assume that the height measurements were measured accurately and that the average height of the 197 soldiers in height group $60'' - 61''$ was $60\frac{1}{2}''$. Then the average deviation of the height of these 197 soldiers from the mean was $67\frac{1}{4} - 60\frac{1}{2}$, or $6\frac{3}{4}''$. In the same way the 317 soldiers had an average deviation of $5\frac{3}{4}$; and so on. The average deviation of group $73 - 74''$ was $73\frac{1}{2} - 67\frac{1}{4}$ or $6\frac{1}{4}$. Some of these deviations are positive and some are negative, because some of the soldiers are shorter than the mean and some are taller.

If we plot these results, preferably by percentage groups, we obtain the curve shown in Fig. 83. This is the curve of error, so-called. The deviations from the mean are regarded as errors. It is similar to the frequency curve of heights. In fact it is the same curve, the only difference being the scale. Mathematicians, physicists and engineers look at their data from the standpoint of errors of observation, and therefore their text books which treat of this subject are called "Precision of Measurements," "Theory of Least Squares," and the like. Natural scientists, however, speak of "Variation." It is all one. The figures show us that small errors occur very often, large errors occur less frequently, and very large errors rarely occur.

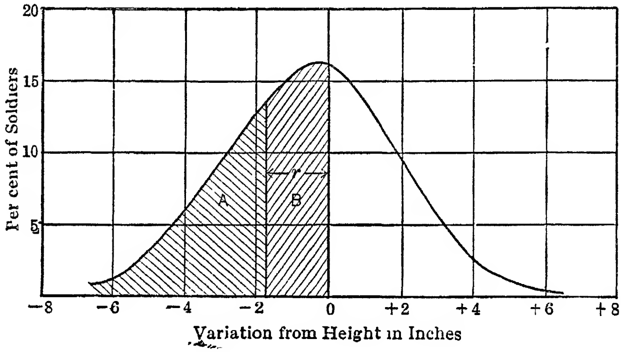


FIG. 83. Percentage Deviation of the Heights of Soldiers from the Mean Height.

Area A = Area B. $r = 1.72$.

In any set of measurements we may assume that errors will exist, and that in natural phenomena there will be variations caused by many factors. We are naturally interested to find out the extent of these variations. We want to know the average deviation and the variation most likely to occur. It will not be possible to go into these matters in great detail in this book. Readers who want to know the theory of these matters must study the theory of probability, or "Least Squares." A few methods of dealing with the subject practically will be given because they have an important use even in elementary statistics. In doing so we will consider first a very simple set of figures.

Standard deviation. — Let us suppose that we have five figures, or statistics, which represent something, no matter what. They are 6, 8, 2, 4, 5. The mean of these figures is 5. The deviations from the mean are respectively 1, 3, −3, −1, and 0. The average deviation, disregarding signs, is their sum divided by 5, or 1.6. A more useful quantity is that called the *standard deviation.* It is obtained by squaring these deviations, finding the average square and taking its square root. If we arrange the data in tabular form we shall better understand the process.

TABLE 146

STATISTICAL DATA

Item.	Deviation from Mean.	Square of Deviation.
(1)	(2)	(3)
6	1	1
8	3	9
2	−3	9
4	−1	1
5	0	0
Sum 25	8[1]	20
Ave. 5	1 6	4

[1] Neglecting signs.

The average square is 4 and $\sqrt{4}$ is 2. Hence 2 is the standard deviation. It will be noticed that the standard deviation gives greater weight to the large deviations than a mere averaging of the deviations does.

Coefficient of variation. — The ratio between the standard variation and the mean is called the coefficient of variation. In the case just mentioned it is 2 ÷ 5, or 0.40. The coefficient of variation is usually expressed decimally. If the variations are very small the coefficient of variation is small. If the variations are large the coefficient of variation is large. In some parts of the country the annual rainfalls do not vary much from year to year. In Massachusetts the coefficient of variation is about 0.17. In other parts of the country there are great fluctuations from year to year. In Arizona the coefficient of variation is 0.50. A low coefficient means, in general, that the figures are more dependable; a high coefficient means that they are likely to be untrustworthy because of their fluctuations. This coefficient is very useful in the study of vital statistics.

Computing the coefficient of variation when data are grouped. — This is likely to cause trouble to the beginner. It is necessary to use care or mistakes will be made. Suppose we have the following items divided into magnitude groups between 0 and 5, the measurements being made to the nearest tenth as shown in columns (1) and (2).

TABLE 147

STATISTICAL DATA

Magnitude group.	Number in group.	Average magnitude.	Product.	Deviation of average magnitude from mean	Square of deviation.	Product.
(1)	(2)	(3)	(4)	(5)	(6)	(7)
0–0.9	6	0 45	2 70	−1 76	3.10	18.60
1–1.9	8	1 45	11.60	−0.76	0 58	4 64
2–2.9	2	2 45	4 90	+0 24	0 06	0.12
3–3 9	4	3.45	13.80	+1.24	1 54	6 16
4–4.9	5	4 45	22.25	+2.24	5.02	25.10
Total	25	....	55.25	....	....	54 62
Mean	....	....	2.21	....	....	2.18

Here we first find the average magnitudes of the numbers in each group, column (3). By multiplying these by the number of items in each group and dividing by the number of items we have (4) the weighted average, or the mean of all the items. This is 2.21. Subtracting the figures in column (3) from 2.21 we have the group deviations in column (5). These are squared (6) and then multiplied by the number of items in each group (7). The sum of the squares divided by 25 gives the average square, *i.e.*, 2.18 and $\sqrt{2.18}$ is 1.48, the standard variation. 1.48 ÷ 2.21 gives 0.67 the coefficient of variation. Unthinking students sometimes multiply the figures in column (5) by those in column (2) before squaring. This is wrong. It is the deviations which are squared. The subsequent process is merely to get the weighted average of the squares.

Probable error. — Neither the average deviation from the mean nor the standard deviation is the one most likely to occur. It is the median deviation, or the median error, which is most likely to occur. It can be shown by calculus that when observations follow the normal law of error, or the normal frequency distribution, *i.e.*, the binomial distribution, the median deviation is about two-thirds of the standard deviation. To be exact, the figure is 0.6745. If we let r stand for this median deviation, this probable error, and if we let x be any individual error, and if $n =$ the number of observations, then, remembering that the sign Σ means "the sum of," we shall see that

$$r = 0.6745\sqrt{\frac{\Sigma x^2}{n-1}}.$$

This is merely the mathematical way of stating what we have just done. Σx^2 means the sum of all the squares of the deviations. $\frac{\Sigma x^2}{n-1}$ is generally used instead of $\frac{\Sigma x^2}{n}$ for the average square, and $\sqrt{\frac{\Sigma x^2}{n-1}}$ means the standard deviation. Where does 0.6745 come from? If we take the curve of error (Fig. 83), and consider the side to the left of the middle ordinate, it will be possible to draw a vertical line somewhere to the left (or the right) of the middle which will divide the area included between the curve and the base line into two equal areas. The length of the abscissa which will do this is 0.6745 that of the standard deviation.

This probable error is quite useful in statistics. One use is that of throwing out of consideration doubtful observations.

Doubtful observations. — Scientists make a distinction between errors and mistakes. Errors are supposed to fall within the limits of probability; mistakes are supposed to be glaring, erratic observations which really ought to be left out of account, or at least not included when the average is computed. We have all had experiences of this kind. In a daily record of the number of bacteria in a filtered water we may find that where most of the figures are less than 25 per cubic centimeter there is one which exceeds 1000. Shall we include this in the average for the month? If we do we unduly raise the average for the month and bring discredit on the filter. And yet there may be no reason for excluding it. It may have been a fact. And a fact is not to be discarded.

The theory of probability give us a means of telling whether it should be included in the average or not. If x is an individual observation and we know the probable error r, as above described, then we shall find that there is an allowable ratio of $\frac{x}{r}$ which depends upon the number of observations. If we had only three observations then any value of the ratio $\frac{x}{r}$ which is greater than about 2 should be regarded as outside the probable variations resulting from the law of chance. If n is 10 the limit of $\frac{x}{r}$ is 3; if n

= 30, then the limit of $\frac{x}{r}$ is 3.5; if n is 100, the limit is 4; if n is 500, the limit is 5, and so on. These values are merely approximate but serve to give a general idea of what may be wisely discarded.

The probability scale. — This ratio of $\frac{x}{r}$, the ratio of any error to the probable, or median, error, is useful in another way, because on the basis of the binomial distribution we can compute the frequency with which any value of $\frac{x}{r}$ is likely to occur. We call this the probability of its occurrence.

If x is any error and r is the probable error then when $\frac{x}{r} = 1$ the chances are even that the error will be x. There are as many chances that the error will be larger than x as that it will be smaller. We may call this a "fifty-fifty" chance, and we may write the probability of its occurrence as $\frac{1}{2}$ or 0.50. If $\frac{x}{r}$ is less than 1 the probability that any error will be less than $\frac{x}{r}$ is less than 0.50, and if $\frac{x}{r}$ is greater than 1 the probability that any error will be less than $\frac{x}{r}$ is greater. In fact we shall find that the following relations hold:

TABLE 148

PROBABILITY

$\frac{x}{r}$	Probability that any error will be less than $\frac{x}{r}$.	$\frac{x}{r}$.	Probability that any error will be less than $\frac{x}{r}$.
(1)	(2)	(1)	(2)
0.0	0.0000	1.7	0.7485
0.1	0.0538	1.8	0.7753
0.2	0.1073	1.9	0.8000
0.3	0.1603	2.0	0.8227
0.4	0.2127	2.1	0.8433
0.5	0.2641	2.2	0.8622
0.6	0.3143	2.3	0.8792
0.7	0.3632	2.4	0.8945
0.8	0.4105	2.5	0.9082
0.9	0.4562	2.6	0.9205
1.0	0.5000	2.7	0.9314
1.1	0.5419	2.8	0.9410
1.2	0.5817	2.9	0.9495
1.3	0.6194	3.0	0.9570
1.4	0.6550	4.0	0.9930
1.5	0.6883	5.0	0.9993
1.6	0.7195	∞	1.000

If we compute the values of $\frac{x}{r}$ which correspond to certain probabilities we have the following approximate figures:

TABLE 149

PROBABILITY

Probability.	$\frac{x}{r}$.	Probability.	$\frac{x}{r}$.
(1)	(2)	(1)	(2)
0 01	0 02	0 80	1.90
0 02	0 04	0.90	2 44
0 03	0 06	0 95	2 91
0 05	0 09	0 98	3.45
0 10	0 19	0 99	3 82
0.20	0 38	0 999	4.887
0 30	0 57	0 9999	5 783
0 40	0 78	0.99999	6 592
0 50	1 00	0.999999	7 258
0 60	1 25	0 9999999	7 967
0 70	1 54		

Probability paper. — Until recently it has been difficult to use the theory of probability in statistical work, but it is now easy. In 1913, my partner, Dr. Allen Hazen, devised a new kind of plotting paper.[1] The percentage scale was so spaced that any set of figures which follow the natural law of probability would plot out not as an ogee curve, but as a straight line. The spacing was based fundamentally on the preceding figures, but it was necessary to take account of the sign of the error, whether positive or negative, and make allowance for this in designing the plotting paper. The 50 per cent, or median line, was placed in the middle of the percentage scale. The other relative distances were as follows. The figures given cover only one side of the 50 per cent line.

[1] This paper may be obtained from the Codex Book Company, 461 Eighth Ave., New York.

TABLE 150

DATA FOR PREPARING PROBABILITY PAPER

Line.	Relative distance	Line.	Relative distance.	Line.	Relative distance.
(1)	(2)	(1)	(2)	(1)	(2)
Per cent.		Per cent.		Per cent.	
50	0 000	17	1 415	0 8	3.573
48	0 074	16	1 474	0 7	3.646
46	0 149	15	1.537	0 6	3 727
44	0 224	14	1.602	0 5	3 821
42	0 300	13	1 670	0 4	3 933
40	0 376	12	1 742	0 3	4 077
38	0 453	11	1 818	0 2	4.267
36	0 531	10	1 906	0.1	4 585
34	0.611	9	1.988	0 09	4 630
32	0.693	8	2 083	0 08	4 685
30	0 777	7	2 188	0 07	4 748
28	0.864	6	2 305	0 06	4 817
26	0.954	5	2 439	0 05	4 900
24	1.047	4	2 596	0 04	5 000
22	1.145	3	2 789	0 03	5.120
20	1 248	2	3 045	0 02	5.290
19	1 302	1	3 450	0.01	5.550
18	1.357	0.9	3 507		

As commonly used the percentage scale was used horizontally, as in Fig. 84. There are sometimes advantages in plotting the percentages as ordinates, as in Figs. 85 and 86. The probability scale may be labeled from 0 to 100 per cent, in either direction, or it may read from 0 to 50 on either side of the median line. It depends upon whether we want to keep the positive and negative errors separate or add them together and consider their magnitude alone.

A few examples of the use of this probability paper will now be given. For a more complete description of this paper the reader is referred to the author's monograph on the "Element of Chance in Sanitation."[1]

[1] Jour. Franklin Institute, July and August, 1916.

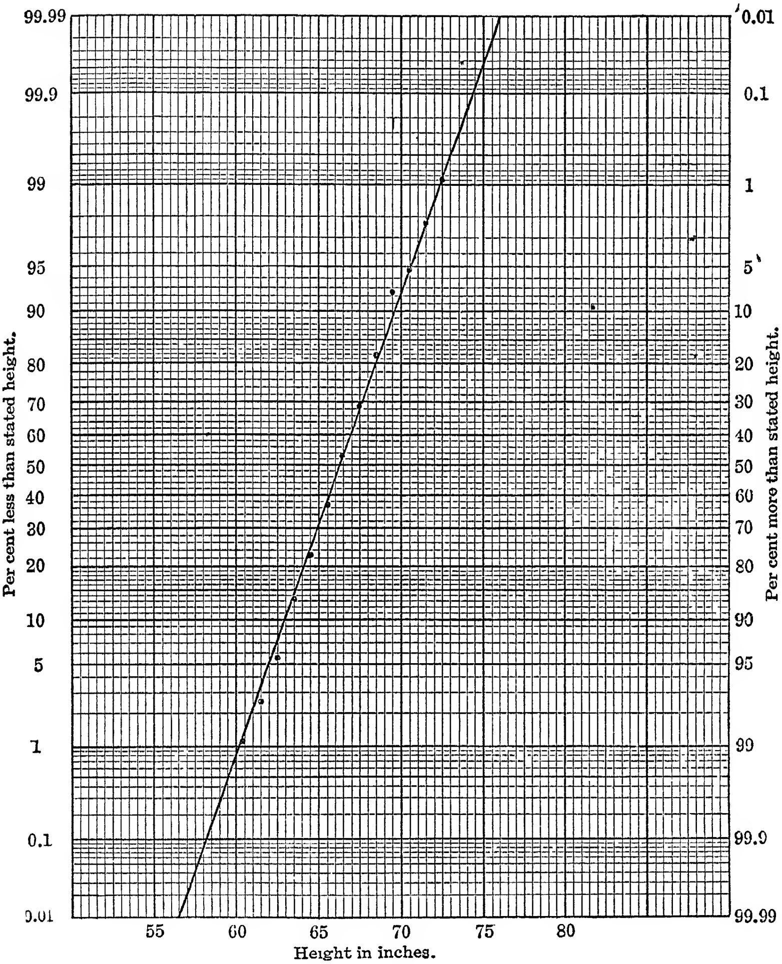


FIG. 84. — Distribution of Soldiers According to Height. Plotted on Arithmetic-Probability Paper.

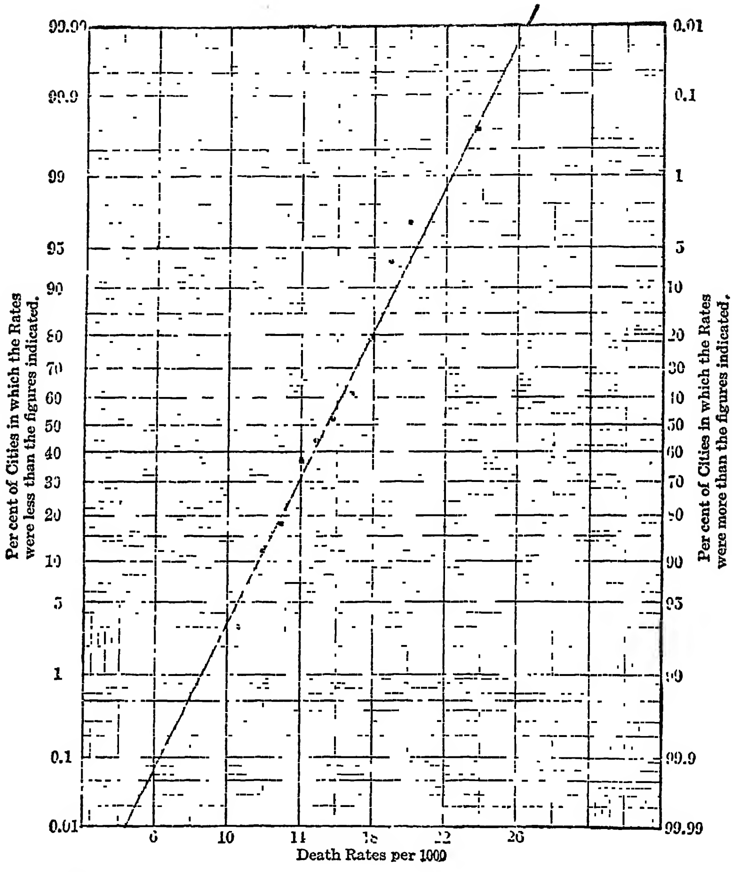


FIG. 85. — Death-rates of Massachusetts Cities and Towns. Plotted on Arithmetic-Probability Paper.

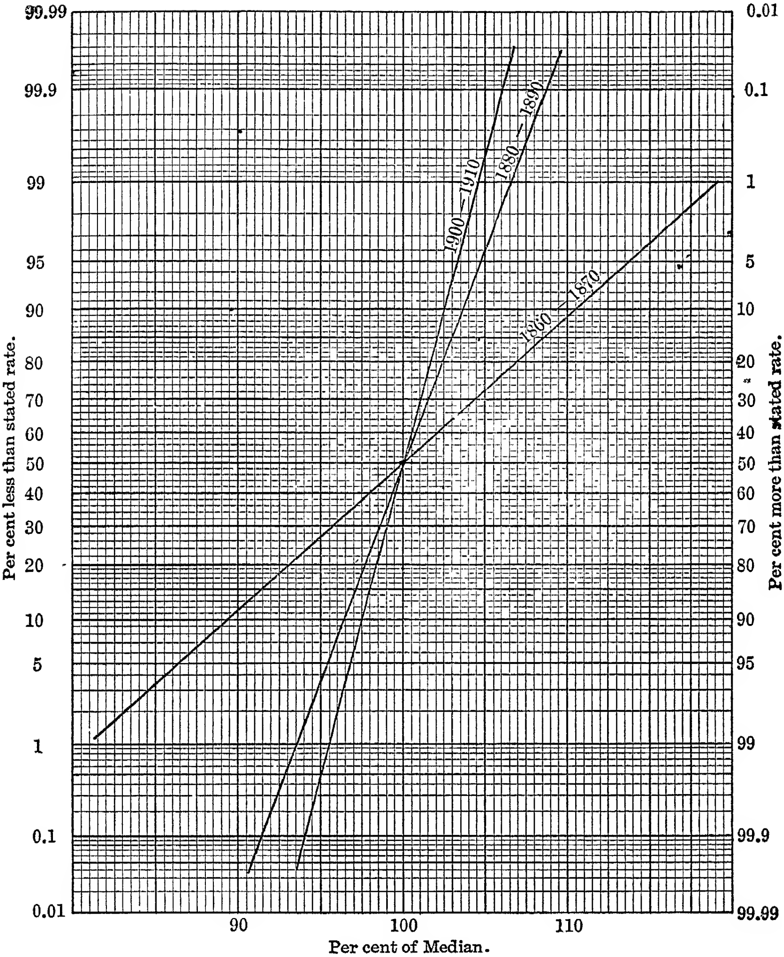


FIG. 86.— Percentage Variation of Death-rates of Massachusetts Cities and Towns for Three Different Decades. Plotted on Arithmetic-Probability Paper.

Examples of use of probability paper. — Fig. 84 shows the distribution of soldiers according to height plotted on probability paper. This is based on the observations with which we have already become familiar. It will be noticed that instead of forming the usual ogee curve the points fall on a straight line.

Fig. 85 shows that the death-rates for Massachusetts cities and towns also plot out on this paper as a straight line. Fig. 86 shows that in 1900–10 the death-rates throughout the state have been more uniform than in 1860–70. This is indicated by the different slope of the lines.

For an example of the use of logarithmic probability paper, see Fig. 89.

Another use of probability. — Bernouilli's theorem gives us another interesting application of the theory of probability.

If we let p represent the probability of an event happening and q the probability of its not happening, then obviously $p + q = 1$. Unless this fundamental condition holds, the laws of probability do not hold. It is always well to see if there are any other factors than p and q.

If we let n represent the number of cases considered, and ϵ the mean error, then Bernouilli says, $\epsilon = \sqrt{npq}$. We need not stop here to prove this, but we may see how it can be used. If n is large then ϵ is a fair measure of the deviation from the standard for it is said that in 2 out of 3 cases the deviation will be less than ϵ; in 19 out of 20 cases less than $2\,\epsilon$; and deviations greater than $4\,\epsilon$ are very rare.

Let us suppose that in a population of 10,000 the general death-rate was 15 per 1000, *i.e.*, 150 deaths in all. Then $n = 10{,}000$; $p = \frac{15}{1000}$; $q = \frac{985}{1000}$; then

$$\epsilon = \sqrt{10{,}000 \times \frac{15}{1000} \times \frac{985}{1000}} = \sqrt{147.75} = 12.15 \text{ deaths},$$

or 1.2 per 1000. A fluctuation of this amount from year to year would not be outside of the bounds of chance phenomena. If the population were 1,000,000 then ϵ would be $\sqrt{14775}$, or 121.5 deaths in 1,000,000 or 0.122 per thousand.

Other criteria than Bernouilli's have been suggested for this computation. The results differ considerably, and none of the methods must be taken as mathematically exact.

Let us suppose we are studying an epidemic of typhoid fever in which all the cases, 120, were actually caused by the public water supply. The population was 50,000. There were two milk dealers: *A* served 40,000 persons; *B* served 10,000 persons. What would be a chance distribution of cases among these two dealers? If they were distributed uniformly we should expect to find among *A*'s customers $\frac{40,000}{50,000}$ of 120, or 96; and among *B*'s customers $\frac{10,000}{50,000}$, or 24. Now what is a reasonable variation from these figures? In the case of *A*,

$$\epsilon = \sqrt{40,000 \times \frac{120}{50,000} \times \frac{49,880}{50,000}} = 10 \text{ approximately.}$$

Therefore, if *A* had any number between 86 and 106 it would be within the bounds of chance. If he had 116 cases it might be a suspicious circumstance. In the case of *B*,

$$\epsilon = \sqrt{10,000 \times \frac{120}{50,000} \times \frac{49,880}{50,000}} = 4.9 \text{ approximately.}$$

If, therefore, *B* had more than 29 cases it would be suspicious.

The frequency curve as a conception. — The frequency curve is something far beyond a statistical tool. Properly conceived it stands for a universal principle. Not all the leaves of a tree are alike, not all shells are alike, soldiers are not all of the same height or weight. We cannot well compare the tallness of pine trees and elm trees without resorting to the frequency curve. One man may say, "The elm tree is the taller; I have seen elms taller than pines." Another says, "That is nothing; pine trees have a greater average height." But the first man is not convinced. He goes back to his own observation and insists that he has seen elms taller than pines. To give the true picture both men need to know the frequency of different heights of both elms and pines.

Are young women as good scholars as young men? Assuming that we have an adequate definition of what is meant by a good scholar, can we settle the question by saying that we have seen young women who were better scholars than young men, or that the average of scholarship is higher among men; must we not know the frequency with which we find good scholars and poor scholars among both men and women? It is quite conceivable that among women we have greater extremes of scholarship than among men, or *vice versa.*

Are women as well fitted for voting as are men? Suffragists used to point to drunken sots and say, "We are better fitted to vote than they are." When they said this they were comparing the end of one frequency curve with the middle or the upper end of the other. Such comparisons are utterly meaningless.

Sometimes we need to make comparisons on the basis of lower limits, sometimes on the basis of upper limits, sometimes we ought to compare modes, sometimes medians, sometimes averages, sometimes we do not know the facts well enough to make comparisons at all: but throughout all realms of thought an appreciation of the fundamental importance of the frequency curve will help us to reason soundly and will prevent us from making false comparisons.

The frequency curve contains in itself the element of beauty. Moons wax and wane; the tide rises and falls; the flowers of spring come, first a few, then many; and they disappear in the same way, a few lingering into summer. It is said that we live in a world of chance. Nothing is more true. We live in a world where many causes are acting with and against each other. We live in a world of frequency curves. Artists and architects recognize this. The ogee curve is the line of beauty.

EXERCISES AND QUESTIONS

1. Find data for and plot an example of a typical symmetrical frequency curve. (Anthropometrical measurements.)

2. Find data for and plot an asymmetrical frequency curve (specific death-rates for scarlet fever, diphtheria, etc.).

3. Describe the application of Bernoulli's Theorem to the chance distribution of cases among milk customers? [See Am. J. P. H., Apr., 1912, p. 296]

4. Construct a model to illustrate the general law of probability [See Rosenau's Preventive Medicine, Chapter on Heredity and Eugenics.]

5. Repeat the coin tossing experiment described in this chapter.

6. Find the height of 50 males (or females) above eighteen years of age, and compute:

a. The average deviation from the mean.
b. The standard deviation.
c. The coefficient of deviation.
d. The probable error.

7. Plot the height records of these persons on "probability paper."

8. Discuss the use of the law of chance in public health studies. (Whipple, Geo. C. The Element of Chance in Sanitation, Jour. Franklin Institute, July and August, 1916.)

9. Prepare a short statistical abstract of the stature of recruits, U. S. A., 1906–15. [Hoffman, Frederick L. Army Anthropometry and Medical Rejection. Newark. Prudential Press, 1918.]

CHAPTER XIV

CORRELATION

Correlation is the word by which the statistician describes the correspondences or relations between series, classes or groups of data; in fact, it is largely for the study of these relationships that statistics are collected.

Deaths from typhoid fever are arranged by months in order to ascertain if there is a fixed relation between the frequency of such deaths and the season of the year; or they are arranged by the age, occupation or place of residence of the decedants in order to learn of any other correspondences which may exist. The heights and weights of men, or women, are compared to see if the variations in height are related to variations in weight; the length of the arm is compared with some other measurement of the body; the heights of sons are compared with the heights of their fathers. These are all simple correlations. Two sets of measurements only are compared.

Often the problem is more complicated. The infant mortality in cities varies with the season, being highest in the summer; the temperature of the air also varies with the season, being highest in the summer; and the statistician desires to ascertain if there is any definite relation, any correlation, between atmospheric temperature and infant mortality. Here there are three elements to be considered — season, temperature and infant mortality. Also the number of flies ordinarily increases with an increased atmospheric temperature, and the question arises "Is there a fixed relation between the increase in the number of flies and the infant mortality?" One naturally asks: "Why not eliminate the temperature of the air and study the direct and simple correlation between flies and mortality? That would, indeed, be the best and safest method, but unfortunately the data may not exist, or cannot be obtained in comparable form. It is, therefore, necessary to devise some way of studying this problem by indirect correlation, or secondary correlation.

Causal relations. — Sometimes statistics are studied merely to determine whether correlation exists between two variables, this result being practically useful. The knowledge that infant mortality increases with the atmospheric temperature is in itself of value to the physician and the health officer. More often perhaps the underlying motive in correlation studies is that of determining cause and effect. In the illustration given the question is, Is the increase in atmospheric temperature the cause of the increased mortality among infants? Is the increase in the number of flies in the summer the cause of the increased infant mortality? Or, to go back to the examples of simple correlation, Is the increased height of men the cause of their increased weight? Is the tallness of a son the effect of the tallness of his father? Does the establishment of correlation also mean that a causal relation has been established? To answer this we must consider what is meant by *cause.*

Jevons[1] says: "By the cause of an event we mean *the circumstances which must have preceded* in order that the event should happen. It is not generally possible to say that an event has one single cause and no more. The cause of the loud explosion in a gun is not simply the pulling of the trigger, which is only the last apparent cause or the occasion of the explosion; the qualities of the powder, the proper form of

[1] Lessons in Logic, p. 239.

the barrel; the existence of some resisting charge; the proper arranging of the percussion cap and powder; the existence of a surrounding atmosphere, are among the circumstances necessary to the loud report of the gun; any of them being absent it would not have occurred." In the above phrase, "the circumstances which must have preceded in order that the event should happen," emphasis must be placed on the word *must*, otherwise our reasoning is *post hoc non propter hoc*.

It is obvious that statistics do not in themselves establish these causal relations. The laws of logic are the primary laws, and the rules of statistics must be subsidiary to them. Westergaard, the celebrated Danish statistician, has recently said (Jour. Am. Stat. Asso., Sept. 1916, p. 259), "that the task of the statistician is not so much to find the causality himself as to help others to find it. The statistician must be content if he can show that certain groups of numbers have marked differences, leaving it to physiology, meteorology and other sciences to explain these differences."

The statistician can prove nothing by his statistics unless he uses them logically.

On the other hand, the statistical arrangements of facts are of the greatest aid in helping to establish causal relations, because by expressing facts by numbers it is possible to concentrate extended experiences into quantities which may be easily and quickly compared.

Correlation and causality. — In studying correlation as a process for determining causality it is necessary to distinguish between the simple correlation which may exist between two variables and the more indirect correlation, or secondary correlation, which occurs when two series of events, both correlated to a third factor, are compared to each other. The former may be safely used to establish a causal relation; in fact, King says (Elements of Statistics, p. 197), that "correlation means that between two series or groups of data there exists some causal relation." In stating this he evidently had in mind the simple correlation between two variables. And, of course, "causal relation" does not mean "sole cause." Besides correlation we must also establish *connection* between the two variables. It is not the task of the statistician to do this. It would be more exact to say that a *causal relation may be shown by establishing a definite correlation between two series, classes or groups of connected data.*

It is chiefly in secondary correlations that we err in our logical processes. In mathematics we learned that "two things which are equal to a third are equal to each other," but it is not necessarily true that two series of events which vary as a third are equal to each other, or even are related to each other at all. Infant mortality increases with the atmospheric temperature in summer; the softness of the asphalt pavements increases with the atmospheric temperature in summer; but we cannot infer that there is any relation between infant mortality and the softness of asphalt pavements.

The actual connection between events is not shown by statistics or by the statistical methods except as the data are interpreted according to the laws of logic.

Let the reader try to answer questions like these. Why is it not true that there is a causal relation between the softness of pavements and infant mortality? Is it, or is it not, true that there is a causal relation between the presence of flies and infant mortality? Which shows the higher degree of correlation with infant mortality—the presence of flies or the softness of asphalt?

Laws of causation. — While we are thinking about correlation and its relation to causation it will not be out of place to refer to the three methods of induction as stated by John Stuart Mill. The cause of an event may be said to be "the circumstances which must have preceded in order that the event should happen."

Mill's first canon is, "If two or more instances of the phenomenon under investigation have only one circumstance in common, the circumstance in which alone all the instances agree is the cause (or effect) of the given phenomenon." This is the method of agreement. The epidemiologist follows this principle when he studies case after case of disease looking for some common antecedent circumstance. Here one instance does not establish proof of a cause, and the larger the number of instances the stronger the proof.

The second canon is "if an instance in which the phenomenon under investigation occurs, and an instance in which it does not occur, have every circumstance in common save one, that one occurring only in the former; the circumstances in which alone the two instances differ is the effect, or the cause, or an indispensable part of the cause, of the phenomenon. This is the method of difference, the method of experiment. This principle also is used in epidemiology.

The third canon is called the joint method. "If two or more instances in which the phenomenon occurs have only one circumstance in common, while two or more instances in which it does not occur have nothing in common save the absence of that circumstance; the circumstance in which alone the two sets of instances (always or invariably) differ, is the effect, or the cause or an indispensable part of the cause, of the phenomenon."

These are sometimes expressed as follows, the large letters, *A*, *B*, *C*, etc., representing antecedents, and the small letters, *a*, *b*, *c*, etc., the consequents.

Method of Agreement

$A\ B\ C$	$a\ b\ c$
$A\ D\ E$	$a\ d\ e$
$A\ F\ G$	$a\ f\ g$
$A\ H\ K$	$a\ h\ k$

Method of Difference

$A\ B\ C$	$a\ b\ c$
$B\ C$	$b\ c$

Joint Method

$A\ B\ C$	$a\ b\ c$
$A\ D\ E$	$a\ d\ e$
$A\ F\ G$	$a\ f\ g$
$A\ H\ K$	$a\ h\ k$
....	....
$P\ Q$	$p\ q$
$R\ S$	$r\ s$
$T\ V$	$t\ v$
$X\ Y$	$x\ y$
	....

Methods of correlation. — Correlations may be divided into two classes: — (1) simple, or primary, and (2) secondary.

Simple correlations are studied as between two variables, these two variables being compared on the basis of magnitude, that is they are compared by grouping.

Secondary correlations are studied when two variables are compared with each other after first being compared to a third variable — such as time or place.

When two variables are so correlated that the numerical values increase and decrease together the correlation is said to be *direct*.

When the correlation is such that the numerical value of one variable increases as that of the other decreases the correlation is said to be *inverse.*

The closeness of correlation is termed the *degree of correlation.* There are mathematical methods of determining the degree of correlation, according to which perfect correlation is represented by *unity* and complete absence of correlation by *zero.*

The following are some of the methods used in the study of correlation:

Simple correlations (two variables compared directly):

1. Plotting of original data.
2. Correlation table (grouping by lines and columns).
3. Correlation model (correlation surface).
4. Plotting of group means (Galton).
5. Computation of coefficient of correlation. (See Elderton's Primer of Statistics.)
6. Use of mathematical formulæ.

Secondary correlations (two variables compared on the basis of a third variable):

1. Comparisons between two plotted lines representing original data, as to:
   (*a*) Parallelism.
   (*b*) Correspondence of fluctuation in time of occurrence and in magnitude.
   (*c*) Correspondence of cycles.
   (*d*) Lag.
   (*e*) Inverse relations.

2. Comparison between two plotted lines, each representing variations from the mean.

3. Comparison between two plotted lines, each representing variations from the moving average (or some smoothed line showing trend).

Galton's coefficient of correlation. — Let us suppose that we have the following pairs of observations. Each *a* has a corresponding *b*. What is the correlation between *a* and *b*? Offhand one can see that in a general way *a* and *b* rise and fall together. But how can we express this relation?

TABLE 151

EXAMPLE OF CORRELATION

	a	b	x	x^2	y	y^2	xy
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	7	4	1	1	0	0	0
	5	2	−1	1	−2	4	2
	6	5	0	0	1	1	0
	3	1	−3	9	−3	9	9
	9	8	3	9	4	16	12
Sum	30	20	.	20	.	30	23
Average	6	4		4	.	6	4 6
σ . .		. .	.	2	. . .	2 45	. . . .

We cannot compare the figures directly. We do not even know that the measurements are the same. *a* may be expressed in feet, and *b* may mean years or something else. What have these two sets of figures in common? The deviations from their means may help us. Let us suppose that *x* represents the deviation of *a* from its mean, 6, and that *y* stands for the deviations of *b* from its mean, 4. Then we can compute the standard deviation of each set of figures, and call these σ_x and σ_y. These we find to be $\sqrt{4}$, or 2, and $\sqrt{6}$, or 2.45. We must now link together the two sets of observations and we do this by finding the products of their deviations, *i.e.*, *xy*, and the average of *xy*, *i.e.*, 4.6. This average value of the product of *x* and *y*, divided by the product of the standard variations, σ_x and σ_y, gives what is called the coefficient of correlation. It may be expressed by formula thus:

Coefficient of correlation, $r = \frac{\Sigma xy}{n\sigma_x\sigma_y}$, in which n is the number of observations, and Σxy the sum of all the xy's. In the example, $\frac{\Sigma xy}{n} = \frac{23}{5} = 4.6$, and the coefficient is $\frac{4.6}{2 \times 2.45} = 0.94$. This is a close correlation between a and b, because 1 represents perfect correlation and 0 no correlation at all.

This method was described by Bravais in 1846, but has come into more common since Pearson showed its advantages in 1896.

Example of low correlation. — In the monthly bulletin of the Department of Health of New Haven, Conn. for Feb., 1918, a radial diagram was given showing that grippe outbreaks in one year are followed by measles the next year, and the statement is made that "the wheel of chance becomes a wheel of certainty." Let us see if these facts will stand the test of correlation. If we place the deaths from grippe in one year side by side with the deaths from measles the following year, we have the following twelve pairs of values for a and b.

TABLE 152

	a	b	x	x^2	y	y^2	xy
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	8	32	−2.25	5 06	16.92	286 29	−38 07
	4	8	−6.25	39 06	− 7.08	50 13	44.25
	15	26	4 75	22 56	10.92	119.25	51 87
	11	5	0.75	0.56	−10.08	101.61	− 7 56
	6	6	−4.25	18.06	− 9.08	82.45	38.59
	8	22	−2 25	5 06	6.92	47.89	−15 57
	16	0	5 75	33 06	−15.08	227.41	−86.71
	7	3	−3.25	10.56	−12.08	145.93	39 26
	12	27	1.75	3.06	11.92	142.09	−20 86
	2	12	−8.25	68 06	− 3 08	9.49	25.41
	9	6	−1.25	1.56	− 9 08	82.45	11.35
	25	34	14.75	217.56	18 92	357.97	279.07
Sum	123	181	....	424 22	...	1652.96	362 75
Average	10.25	15.08	....	35 35	.....	137.75	......
σ	....	.....	....	5.95	.....	11.74	......

It will be seen that the coefficient of correlation is

$$r = \frac{\Sigma xy}{n\sigma_x\sigma_y} = \frac{362.75}{12 \times 5.95 \times 11.74} = 0.43.$$

This is not a high correlation. Whether it is significant or not depends upon the probable error, which may be taken as $.6745 \frac{1 - r^2}{\sqrt{n}}$. In this case the probable error is 0.16 and the entire result may be expressed thus: —

$$0.43 \pm 0.16$$

Bowley says that the coefficient of correlation, to be significant, must be at least six times the probable error. In this case 0.43 is only about three times 0.16, hence it is not significant. It follows, therefore, that the statement that grippe is followed by measles a year later has little to substantiate it, if all the facts are considered. If we leave out a few exceptional years there does appear to be a general tendency for measles to follow grippe. But what right is there to leave out some of the facts? If they are mistakes they should be left out, otherwise they should be considered in drawing conclusions.

A few years ago a sanitary chemist tried to show a relation between the color of water and the typhoid fever death-rates in Massachusetts water supplies. Computations of the coefficient of correlation for 54 places where surface water was used gave a correlation of 0.16 ± 0.13, while for 33 places where ground water was used it was $0.30 \pm .16$. In other words there was practically no correlation. In the same cities the correlations between the general death-rates and the typhoid fever death-rates were $0.59 \pm .09$ and $0.56 \pm .11$ respectively.

On the other hand, the Eldertons found the coefficient of correlation between the length and breadth of shells to be 0.95; that between the ages of husbands and wives, 0.91.

The student will find the use of the coefficient of correlation an admirable weapon for exploding false theories.

A recent example of lack of correlation. — The Municipal Tuberculosis Sanitarium of Chicago, in its annual report for 1917, has published an interesting series of diagrams illustrative of the lack of correlation between housing and tuberculosis. Fig. 87 is one of these. The districts are arranged in order of occurrence of tuberculosis. The one-scale rectangles, appropriately divided according to the character of rooms, fail to show any progression coincident with tuberculosis under Chicago conditions.

The correlation table. — The correlation table is arranged much like a simple plot. There is a horizontal and a vertical arrangement of groups. This tabulation shows to the eye the relation between the two quantities. In Table 153 we see the correlation between the ages of husband and wife is fairly close. Of 669 wives in age-group 40–44, 309 were married to husbands in the same age-group. There is a slight tendency for husbands to be slightly older than their wives. The figures are not symmetrically arranged around the mode.

The correlation model is used but little. A description of its construction and use may be found in works on statistical methods.

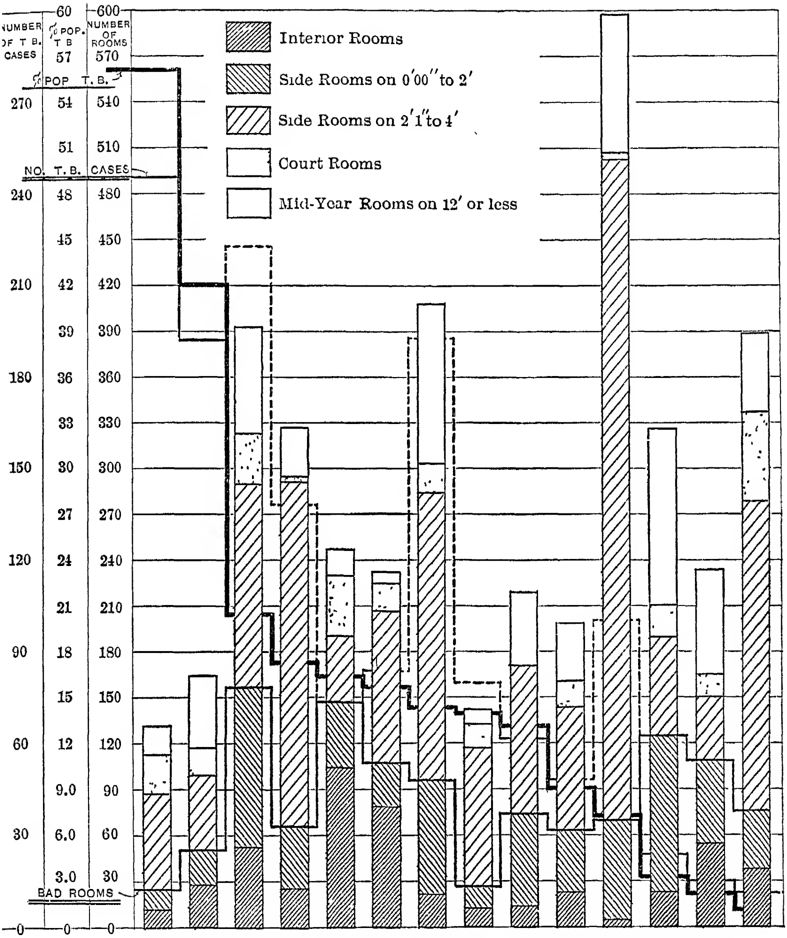


Fig. 87. — Diagram Showing Lack of Correlation between Interior Rooms in Certain Chicago Blocks and Tuberculosis Morbidity.

TABLE 153

CORRELATION BETWEEN (1) THE AGE OF WIFE, (2) THE AGE OF HUSBAND, FOR ALL HUSBANDS AND WIVES IN ENGLAND AND WALES WHO WERE RESIDING TOGETHER ON THE NIGHT OF THE CENSUS, 1901. (CENSUS, 1901, SUMMARY TABLES, P. 182.) TABLE BASED ON 5,317,520 PAIRS; CONDENSED BY OMITTING 000'S

(From Yule's Theory of Statistics, p. 159.)

Ages of husbands	Ages of wives.															Total
	15-	20-	25-	30-	35-	40-	45-	50-	55-	60-	65-	70-	75-	80-	85-	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10	(11)	(12)	(13)	(14)	(15)	(16)	(17)
15-	2	2														4
20-	16	173	46	4	1											240
25-	4	185	402	84	10	2	1									688
30-	1	41	265	411	84	12	2	1								817
35-	..	9	69	251	369	80	12	2	1							793
40-		3	17	71	219	309	66	12	2	1						700
45-	.	1	6	20	66	178	252	59	10	2	1					595
50-	.		2	8	19	57	146	195	44	10	2					483
55-	. .		1	3	8	18	46	110	141	35	6	1				369
60-				1	3	8	16	39	81	101	23	4	1			277
65-				1	1	3	6	11	26	53	58	13	2	1		175
70-					1	1	2	5	8	18	31	31	6	1		104
75-	. .					1	1	2	3	5	10	14	12	2		50
80-								1	1	1	2	4	5	3	1	18
85-											1	1	1	1		4
Total	23	414	808	854	781	669	550	437	317	226	134	68	27	8	1	5317

Use of mathematical formulæ. — It is often desirable to find the equation of a straight line or curve drawn through a series of points. This is not difficult, but it requires a longer description than can be given here. The student can find good descriptions of the methods used in standard mathematical books.

Secondary correlation. — The correlation of two variables is often shown by plotting each against a third quantity, which latter varies in a regular manner. Thus in Fig. 72 we have the number of cases of typhoid fever plotted as ordinates with months as abscissæ, and we have also the atmospheric temperature plotted as ordinates with months as abscissæ. Here we see that there is a general correspondence between the two curves and we say that there is correlation between the two. One must be very careful in using the graphic method in this way. We may have a diagram in which the correspondence between the two plotted lines is very definite *except occasionally,* yet these occasional lapses may be enough to upset the correlation. Again two lines may rise and fall together in point of time, and they may even rise and fall apparently the same amounts, yet this may be an incident depending on the scales used. Finally we must not forget that this sort of correlation — where two quantities vary as a third — does not establish causality.

In Fig. 73 we have typhoid fever death-rates and population supplied with filtered water, both plotted with time as the abscissæ; and we notice that as one line goes up the other goes down, giving a sort of inverse correspondence. We are not justified however in calling this a close correlation. Certainly we are not justified in saying that one is the cause of the other. It may be true, and few will dispute the fact that the filtration of polluted water tends to reduce the typhoid fever death-rate among the consumers of the water, but such a diagram as this does not prove it. As Phelps[1] says, we might plot a line showing the increase in the number of telephones which would very much resemble that of the population supplied with filtered water. Pearson does well to call this correlation based on comparison with a "common mutual," a "*spurious correlation.*" A good many false conclusions have been based on statistics treated in this way.

[1] Am. Jour. Pub. Health, 1917, p. 23.

The lag. — When two lines are plotted with the scale of abscissæ in common to both variables it often happens that one line changes in curvature after the other; it lags behind it. Sometimes this lag is very regular, sometimes it is more or less irregular. This lag does not necessarily show lack of correlation. It may, on the other hand, result from cause and effect. It is obvious that a cause must precede in time the effect produced by that cause. It may require a certain interval of time for the cause to make itself felt, and this naturally would produce a lag. For example, let us suppose that it takes ten days after a typhoid infection for the victim to "come down" with the disease; then a plotted line showing by days the number of cases of typhoid fever would lag behind a line showing infection of the water-supply, — if we can imagine such facts to be plotted. Conversely, if we had the two plotted lines we might compute the length of the incubation period of typhoid fever by measuring the lag. If the comparison is between the dates of infection and the dates of deaths from typhoid fever, then, of course, the lag is much longer as it includes not only the period of incubation, but also the run of the disease, and this is not the same for all persons.

A device sometimes used is the "set back." If we are comparing two curves, one of which is supposed to represent the cause of the other, we may plot the causal curve on the true dates and we may set back the dates of the resulting curve by an amount equal to the lag. Correlation will then be indicated by the correspondence of the curves. This presupposes that the amount of the lag is known.

In comparing lagging curves which are apparently correlative it is important to distinguish between cause and effect. As we have reiterated, it is not the function of correlation to demonstrate causality.

Fig. 72 is an example of the use of the set back. This is a correlation between typhoid fever deaths and atmospheric temperatures, the deaths being set back two months.

Coefficient of correlation and the lag. — It is possible to deal with the lag analytically instead of graphically. We may find that by comparing two series of statistics, date for date, the coefficient of correlation is low; by setting one series back a day and recomputing the coefficient we may find it higher; by setting back two days the coefficient may be higher still; and by using greater set backs the coefficient may increase to a maximum, and beyond that point it may decrease. The set back which produces the highest correlation may be taken as a measure of the lag.

All such matters as these are fully discussed in the textbooks of general statistics.

Other secondary correlations. — Sometimes the secondary character of a correlation is not as clearly revealed as in the case of two plotted lines with common abscissæ. It has been noticed that poliomyelitis cases seem to follow the river valleys; what is the real correlation here? It does not appear to be a direct correlation. One says that fleas are correlated with the river valleys, and that, secondarily, the disease is correlated with the fleas; another says that the lines of transportation are along the river valleys and that the real correlation is between poliomyelitis and the contact of people incident to intercommunication.

The whole matter of correlation is almost inseparable from the science of logic.

The epidemiologist's use of correlation. — Epidemiology, a branch of medical science, is based fundamentally on the laws of cause and effect. The epidemiologist is continually searching for the cause of outbreaks of disease in order that they may be checked and future outbreaks prevented. In his studies he uses statistics continually and is of necessity mightily interested in correlation. The successful epidemiologist must have a nose for facts, must be able to analyze these facts skillfully and draw logical conclusions from them.

The influence of a particular factor as a cause of disease is often studied by means of statistics. For example, the filtration of a public water-supply may be followed by a reduction of the typhoid fever death-rate among the water takers. This is a sort of correlation, — one change being followed by another. We know, moreover, by inductive reasoning from many such occurrences in the past and also from experimental evidence that this is a correlation which implies causality. In using this method of reasoning, however, it is important to know that the change in the water-supply was the *only* change which occurred.

There are scores of instances where this method of reasoning has been used. In Panama the abolition of the mosquito reduced the death-rate from yellow fever. The evidence points to this as a clear-cut case not only of correlation, but causality. In Panama also the malaria has been greatly reduced since the anti-mosquito work was begun. But here we find that quinine has been used as an additional agent of prevention. In this case therefore we have had two factors changing at about the same time. From experimental evidence there is no doubt in regard to the causal relations between malaria and the Anopheles mosquito, but statistically the evidence is not as strong as in the case of yellow fever.

In some of the old studies of typhoid fever it was found that the death-rate decreased after the introduction of a sewerage system. This was accompanied by an abolition of house privies. Now it was probably the abolition of the old privies, not the building of the new sewers which produced the result. In other cases a public water-supply was installed at the same time that the sewers were built. A reduction in the typhoid death-rate following these events may have been due to either or to both.

The fact should not be overlooked that when epidemics occur there is not infrequently more than a single factor involved. Sometimes an outbreak can be traced to a single initial case, but just as in lighting a fire the match is applied to the paper, the burning paper sets fire to the kindling and the burning kindling sets fire to the coal, so a single case may start infections which may be scattered in various ways. It is important for the epidemiologist to find all of these methods of transmission.

Sometimes the epidemiologist is obliged to base his action upon statistics which show correlation without waiting to determine whether this correlation also means causation. For example, in the recent pandemic of influenza a certain vaccine, supposed to have a prophylactic value, was used upon several hundred persons. The question arose, "Shall this vaccine be distributed and generally used?" The data first collected showed a fair degree of correlation between the use of the vaccine and apparent protection against the disease, and on the strength of this finding the vaccine was distributed. Later studies, however, failed to corroborate the correlation at first noticed, and showed that there was no causal relation between the use of the vaccine and failure of persons to take the disease. It was really a case of correlation without causation, — *post hoc non propter hoc.* And yet the health authorities, compelled to take action one way or the other, were right in basing action on the supposed correlation.

EXERCISES AND QUESTIONS

1. Is there a correlation between epidemics of poliomyelitis and rainfall? [See Am. J. P. H., Sept., 1917, p. 813.]

2. Is there a higher correlation between flies and diarrhœal diseases among children than between diarrhœal diseases and other factors? [See Am. J. P. H., Feb., 1916, p. 143, also Mar., 1914, p. 184.]

3. Is there a correlation between pneumonia and influenza? Is there a causal relation? [See Am. J. P. H., Apr., 1916, p. 316.]

4. Is there a correlation between tuberculosis and housing? [See Am. A. J. P. H., Jan. 1913, p. 24.]

5. Look up Dr. Fulton's extravaganza on the subject of statistical logic as applied to the problem of prostitution. [See Am. J. P. H., July, 1913, p. 661.]

6. Study the correlation between plague and fleas. [Am. J. P. H., Aug., 1918, p. 572.] Is there strong presumptive evidence that infantile paralysis is spread by fleas?

7. Express Mill's three canons of logic in your own words.

8. Give examples of each in the field of epidemiology.

9. What is meant by quantitative induction? What part do statistics play in this? [See Jevon's Lessons in Logic, Chap. XXIX.]

CHAPTER XV

LIFE TABLES

To the popular mind there is something mysterious and awesome about a life table. The insurance agent, wishing to sell you a policy, asks your age, consults a printed table and tells your "expectation of life" as so many years. What does this mean and how does he arrive at this expectation of life? It does not mean that *you* will live so many years and then die. It means that it has been found in the past that most men who have attained your age have lived so many years after reaching that age. It cannot apply to everyone. *You* may live to be a hundred years old or you may die to-morrow. The future is uncertain for every individual. But the probability of your future longevity can be determined by making a statistical study of a large group of people who have attained your age, to find out the average number of years which they lived after reaching that age. Instead of using the average, *i.e.*, the *mean* we might find the *median* number of years lived, or even the *mode*. All three methods have been suggested, but that based on the mean is the one commonly used. Thus we see that there is nothing mysterious about the "expectation of life"; it has no divine origin. It is merely the application of the ordinary methods of statistics to the experience of mankind in living beyond a given age.

Probability of living a year. — Although the expectation of life is used by insurance agents to impress the prospective purchaser with the fleeting character of human life, the rates of insurance are not based directly on this expectation, but on the probability of a person of given age living to be one year older. It is this chance of living from year to year, coupled with the growth of money at compound interest which determines what premium the insured at any age must pay. These actuarial methods are too complicated to be entered into here. In the very early days life insurance was virtually a lottery; now it is based on experience. If, as a result of better living conditions, the longevity of the insured is greater than the experience upon which the rates were based, the insurance company is the gainer because the premiums are continued for a longer time and the final payment of the policy is postponed. If the company is a so-called mutual company, the benefit of increased longevity of the insured is distributed among the policy holders in the form of rebates. But should the longevity of the insured prove to be less than the experience upon which the rates were based the opposite condition would prevail.

What is the chance of a person living from year to year? Obviously it is one minus the chance of dying. The chance of dying within one year at any age is nothing else than our old friend the specific death-rate for the given age. Thus if at age 20 the specific death-rate is 7.80 per 1000, the chance of dying within the year is 780 in 100,000, 0.0078 in 1, or 1 chance in 128; at age 50 the chance is 0.01378, or 1 in 73; at age 70 it is 0.06199 or 1 in 16; at age 80 it is 0.14447, or 1 in 7; at age 90, it is 0.45454, or 1 in 2.2.

The chance of living through the year is 1 less the chance of dying. At age 20 the chance of living through the year is 99,220 in 100,000, *i.e.*, 0.9920; at age 50 it is 0.98622; at age 70, 0.93801; at age 80 it is 0.85553; at 90 it is 0.54546. Or, to put it in another form, — at age 20 the chance of living a year is 99.2 in a hundred; at age 50, 98.6; at age 70, 93.8; at age 80, 85.5; at age 90, 54.5 in a hundred.

Thus a column showing for each age of life the probability of living a year can be made by subtracting the yearly specific death-rates from unity, and expressing the results in decimal parts of 1. We might call these specific life-rates, as they are the converse of the specific death-rates.

This specific life-rate is never used in ordinary discussion, and there is little reason for using it, as it is probably better to think in terms of specific death-rates. It is the deaths which we are always trying to postpone. A table of specific death-rates and specific life-rates would look like this.

TABLE **154**

SPECIFIC DEATH-RATES AND SPECIFIC LIFE-RATES

(Abridged from the American Experience Mortality Table.)

Age.	Population alive at mid-year.	Specific death-rate per 100,000 (number dying annually).	Specific life-rate per 100,000 (number living through the year).
(1)	(2)	(3)	(4)
10	100,000	749	99,251
20	100,000	780	99,220
30	100,000	843	99,157
40	100,000	979	99,021
50	100,000	1,378	98,622
60	100,000	2,669	97,331
70	100,000	6,199	93,801
80	100,000	14,447	85,553
90	100,000	45,454	54,546

One reason why specific death-rates are not used more commonly is because people do not clearly understand them. The base, *i.e.*, 100,000 persons, remains constant for all ages. Actually the number of persons alive is constantly decreasing as age advances. One says "you start with 100,000 persons at age 10 and kill off 749 in one year, but the next year you have 100,000 again. I don't understand it."

Now life tables are definitely related to specific death-rates and they take into account this decreasing population.

Mortality tables. — In order to make a life table we may first select some large class of people and determine the specific death-rates for each year of age. We start with a certain number of people alive at a certain age. The insurance companies commonly use age 10 because most insured persons are older than that, but we might use any other age. We might use age 0, and in making a life table for a general population this would be done. As an illustration, however, let us take the American Experience Mortality Table, which starts at age 10 and which is limited to males. Another reason for taking age 10 is that it is a round number not far from the age at which the specific death-rate is the lowest.

For convenience we start with 100,000 as a round number of persons alive at age 10. This number is called the *radix* of the computation. We might use a million or a thousand, but the former is hardly warranted by the precision of our specific death-rates, while the latter gives too many decimals.

In the table, column (1) gives the age, and column (5) the corresponding specific death-rates obtained from the original data. In column (2) we start with 100,000 persons alive at age 10, of these

92,637	lived to	age	20
85,441	"	"	30
78,106	"	"	40
69,804	"	"	50
57,917	"	"	60
38,569	"	"	70
14,474	"	"	80
847	"	"	90
0	"	"	96

These figures were obtained as follows: — 100,000 were alive at the beginning of age 10 and 749 per 100,000 died

TABLE 155

AMERICAN EXPERIENCE MORTALITY TABLE

Age	Number living	Number dying	No of years expectation of life.	No dying of each 100,000 annually.	Age.	Number living	Number dying	No. of years expectation of life	No. dying of each 100,000 annually
(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)
10	100,000	749	48 72	749	53	66,797	1,091	18 79	1,633
11	99,251	746	48 08	752	54	65,706	1,143	18 09	1,740
12	98,505	743	47 45	754	55	64,563	1,199	17 40	1,857
13	97,762	740	46 80	757	56	63,364	1,260	16 72	1,988
14	97,022	737	46 16	760	57	62,104	1,325	16 05	2,133
15	96,285	735	45 50	763	58	60,779	1,394	15 39	2,294
16	95,550	732	44 85	766	59	59,385	1,468	14 74	2,472
17	94,818	729	44 19	769	60	57,917	1,546	14 10	2,669
18	94,089	727	43 53	773	61	56,371	1,628	13 47	2,888
19	93,362	725	42 87	776	62	54,743	1,713	12 86	3,129
20	92,637	723	42 20	780	63	53,030	1,800	12 26	3,394
21	91,914	722	41 53	785	64	51,230	1,889	11 67	3,687
22	91,192	721	40 85	791	65	49,341	1,980	11 10	4,013
23	90,471	720	40 17	796	66	47,361	2,070	10 54	4,371
24	89,751	719	39 49	801	67	45,291	2,158	10 00	4,765
25	89,032	718	38 81	806	68	43,133	2,243	9 47	5,200
26	88,314	718	38 12	813	69	40,890	2,321	8 97	5,676
27	87,596	718	37 43	820	70	38,569	2,391	8 48	6,199
28	86,878	718	36 73	826	71	36,178	2,448	8 00	6,766
29	86,160	719	36 03	834	72	33,730	2,487	7 55	7,373
30	85,441	720	35 33	843	73	31,243	2,505	7 11	8,018
31	84,721	721	34 63	851	74	28,738	2,501	6 68	8,703
32	84,000	723	33 92	861	75	26,237	2,476	6 27	9,437
33	83,277	726	33 21	872	76	23,761	2,431	5 88	10,231
34	82,551	729	32 50	883	77	21,330	2,369	5 49	11,106
35	81,822	732	31 78	895	78	18,961	2,291	5 11	12,083
36	81,090	737	31 07	909	79	16 670	2,196	4 74	13,173
37	80,353	742	30 35	923	80	14,474	2,091	4 39	14,447
38	79,611	749	29 62	941	81	12,383	1,964	4 05	15,860
39	78,862	756	28 90	959	82	10,419	1,816	3 71	17,430
40	78,106	765	28 18	979	83	8,603	1,648	3 39	19,156
41	77,341	774	27 45	1,001	84	6,955	1,470	3 08	21,136
42	76,567	785	26 72	1,025	85	5,485	1,292	2 77	23,555
43	75,782	797	26 00	1,052	86	4,193	1,114	2 47	26,568
44	74,985	812	25 27	1,083	87	3,079	933	2 18	30,302
45	74,173	828	24 54	1,116	88	2,146	744	1 91	34,669
46	73,345	848	23 81	1,156	89	1,402	555	1 66	39,586
47	72,497	870	23 08	1,200	90	847	385	1 42	45,454
48	71,627	896	22 36	1,251	91	462	246	1 19	53,247
49	70,731	927	21 63	1,311	92	216	137	0 98	63,426
50	69,804	962	20 91	1,378	93	79	58	0 80	73,418
51	68,842	1,001	20 20	1,454	94	21	18	0 64	85,714
52	67,841	1,044	19 49	1,539	95	3	3	0 50	100,000

during the year. Consequently, the number alive at age 11 was 100,000 − 749 = 99,251. In the next year the specific death-rate was 752 per 100,000. The number dying was, therefore, $99{,}251 \times \frac{752}{100{,}000} = 746$, and the number alive at age 12 was 99,251 − 746 = 98,505. And so on. The number dying each year is given in column (3), the number living in column (2). At age 96 all were dead.

These are the facts of the case, now how shall we use them? There are three ways, which correspond to the mode, the median and the mean, and they are called respectively the "most probable life-time," the "Vie Probable," and the "Expectation of Life." It might be better to call these respectively the "modish expectation," the "median expectation," and the "average expectation," but the old terms are here used for purposes of identification.

The "most probable life-time." — The figures in column 3 form a frequency curve, the mode of which is 2505. There are more deaths at age 73 (*i.e.*, age 73–74) than at any other age. 73 is the fashionable, modish age to die. The chance of dying at that age is greater than at any other age.

The difference between a given age and 73 years is called "the most probable life-time." At age 10, it is 73 − 10 = 63; at age 20 it is 53; and so on. Above the age 73 the "most probable life-time" becomes a negative quantity, and this is the objection to the use of this computation. It is applicable only to the first part of the frequency curve.

The "Vie Probable." — The "Vie Probable" is the number of years which a person (at a stated age) has an even chance of living. It is the difference between a given age and the age at which the number of persons alive is one-half the number alive at the given age. The latter is the median age to which the persons who passed the given age lived.

At age 10 there are 100,000 persons alive. One-half of this number, *i.e.*, 50,000, are alive at age 64.5±. Hence 64.5 − 10 = 54.5 is the "vie probable." In this period of time the chance of living or dying is just even.

At age 20, there are 92,637 persons alive. One-half of this number, *i.e.*, 46,318, were still alive at age 66.5. Hence the "vie probable," for age 20 is 66.5 − 20 = 46.5 years.

The "Expectation of Life." — The "Expectation of life" means the average number of years that persons of a given age will probably survive. It is obtained by finding the average of the lengths of life of all the persons who lived beyond the given age.

Thus of the 100,000 alive at age 10, 3 lived to the age of 95, that is, they lived for (95 − 10 =) 85 years after the age of 10. 21 lived to age 94, *i.e.*, 84 years. But these 21 include the 3 who lived to age 95, so there were 18 who lived 84 years. 79 lived 83 years, but these include both the 3 and the 18, so in addition to them (79 − 21 =) 58 lived 82 years. And so on. The weighted averages of all of these lives gives what is called the expectation of life. These results are given in column (4).

In obtaining the figures for column (4) it is most convenient to begin at the higher ages and work backward.

At the beginning of age 95, there were 3 persons alive; at the end there were none alive. Not knowing at what part of the year they died the best assumption is that they died (on an average) at the middle of the year, *i.e.*, they lived one-half year. Hence at age 95, the average length of the lives was $\frac{3 \times \frac{1}{2}}{3} = 0.50$ year. This is the expectation of life at age 95.

At age 94, 21 persons were alive. 3 of these lived $1\frac{1}{2}$ years each; the other 18 died within the year, and may be said to have lived one-half year. Hence we have:

$$\begin{array}{rl} 3 \times 1.5 = & 4.5 \\ 18 \times 0.5 = & \underline{9.0} \\ \overline{21} \qquad & 13.5 \quad \text{and } 13.5 \div 21 = 0.64 \text{ yr.} \end{array}$$

Hence at age 94 the expectation of life is 0.64 year.

At age 93 we have:

$$\begin{array}{rl} 3 \times 2.5 = & 7.5 \\ 18 \times 1.5 = & 27.0 \\ 58 \times 0.5 = & \underline{29.0} \\ \overline{79} & 63.5 \end{array}$$ and $63.5 \div 79 = 0.80$ year.

In this way we find that at age 10, the average number of years lived by those who passed age 10, was 48.72 years. At age 20 it was 42.20 years; at age 30 it was 35.33 years, etc.

Comparison of the three results. — The U. S. Life Tables for 1910 give the "complete expectation of life" (computed on the basis of the mean), and from the tables may be obtained the "most probable life-time" (based on the mode) and the "vie probable" (based on the median). The following figures give the results for age zero, that is, they show the expectation of life at birth.

TABLE 156

COMPARISON OF "EXPECTATION OF LIFE," "VIE PROBABLE" AND "MOST PROBABLE LIFE-TIME"

Original registration states.	Expectation of life (Mean.)	"Vie probable"[1] (Median.)	Most probable[1] life-time. (Mode.)
(1)	(2)	(3)	(4)
White males	50 23	59 30	74 0
White females	53 62	63 27	73 5
Negro males	34 05	34 85	59 5
Negro females	37 67	40 58	65 5
White males in cities	47.32	55 00	68.5
White males in rural part	55 06	65 33	76.5
White females in cities	51 39	60 73	71.5
White females in rural part	57.35	67 38	76.5
Males in Massachusetts	49 33	58 82	69.5
Females in Massachusetts	53.06	62 74	74.5

[1] Approximate.

Life tables based on living population. — Life tables may also be computed in another way. They are based on the population living at each age as shown by the census returns or by data collected by the insurance companies. Thus we may assume that the figures in column (2) have been obtained in this way. If we start with 100,000 persons alive at age 10 and find that 99,251 were alive at age 11 then the number of deaths during the year must have been 100,000 − 99,251, or 749. Between ages 11 and 12 the deaths were 99,251 − 98,505, or 746; and so on. By this method we compute the deaths, and we may also compute the specific death-rates for each age. This method justifies the use of the term *life tables*, as the results are based on the living and not on the dying. It is obvious that migrations of population interfere somewhat with this method. It is obvious, also, that concentrations of population on the round numbers present another difficulty. As a matter of practice the ragged data must be smoothed out before a life table can be constructed; otherwise the computed expectations of life would themselves be erratic. These errors of round numbers creep into the computations of specific death-rates, so that in any case it is necessary to do a certain amount of "smoothing" before computing life tables. One method commonly used is that known as "osculatory interpolation," which may be found described in such books as Vital Statistics Explained, by Burn.

Still another method of computing a life table is to base it wholly on the distribution of deaths, making use of certain mathematical formulas for frequency curves.[1]

Mathematical formula for computing the expectation of life. — There is a mathematical formula for the computation of the expectation of life by the use of which the labor may be shortened. It is usually stated as follows:

[1] Arne Fisher. Note on the Construction of Mortality Tables by means of Compound Frequency Curves. Proc. Casualty Actuarial and Statistical Society of America, Vol. IV, Pt. 1, No. 9.

$$\mathring{e}_x = \frac{\frac{1}{2} l_x + l_{(x+1)} + l_{(x+2)} + l_{(x+3)} + \cdots}{l_x} = \frac{1}{2} + Q.$$

$$Q = \frac{l_{(x+1)} + l_{(x+2)} + l_{(x+3)} + \cdots}{l_x}.$$

$\mathring{e}_x$ = expectation of life, in years, at age x.
l_x = number of persons living at age x.
$l_{(x+1)}$ = number of persons living at age $x + 1$.
$l_{(x+2)}$ = number of persons living at age $x + 2$, etc.

For a more detailed description of these methods the reader is referred to such books as United States Life Tables, 1910, Bureau of the Census, prepared by Prof. James W. Glover and published in 1916; Life Assurance Primer, by Henry Moir; Vital Statistics, by Newsholme; Mortality Laws and Statistics, by Robert Henderson.

Early history of life tables. — It is not surprising that most of the life tables which have been computed have been confined to males of insurable age. Halley, the British astronomer, famous for the comet which bears his name, was the first to use the method. This was in 1692 and related to the town of Breslau. Other famous tables are the Northampton Table of 1783, the Carlisle Table of 1815 and Dr. Farr's English Table of 1851.

In 1843 seventeen English insurance companies combined their experiences and published a table known as the Actuaries or Combined Experience Table. It was based on 84,000 policies. The American Experience Table of Mortality, now recognized by the insurance companies as the standard for America, was formed by Sheppard Homans in 1868. It is supposed to have been based on the experience of the Mutual Life Insurance Company of New York.

In 1869 the H^M Table was published in England. H^M means Healthy Males. It was based on 180,000 policies. Then there is an O^M Table (ordinary life, males) based on over 400,000 lives. This is the Canadian standard.

Recent life tables. — In 1898 Dr. Samuel W. Abbott published in the annual report of the Massachusetts State Board of Health for that year,[1] a life table for Massachusetts. This is one of our best American papers on the subject.

Dr. Guilfoy, the statistician of the New York City Board of Health, has published the following interesting comparison between the expectations of life in 1879–81 and 1909–11. The changes which have taken place durıng the interval are striking. The figures are as follows:

TABLE 157

APPROXIMATE LIFE TABLES FOR THE CITY OF NEW YORK BASED ON MORTALITY RETURNS FOR THE TRIENNIA 1879–1881 AND 1909–1911

Years of mortalıty, ages	Expectatıon of lıfe, 1879 to 1881.			Expectatıon of lıfe, 1909 to 1911.			Gain (+) or loss (−) ın years of expectancy.		
	Males.	Females.	Persons	Males	Females.	Persons.	Males	Females.	Persons.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
−5	39 7	42 8	41 3	50 1	53 8	51 9	+10 4	+11 0	+10 6
5	44 9	47 7	46 3	49 4	52 9	51 1	+ 4 5	+ 5 2	+ 4 8
10	42 4	45 3	43 8	45 2	48 7	46 9	+ 2.8	+ 3 4	+ 3 1
15	38 2	41.2	39 7	40 8	44 2	42 5	+ 2 6	+ 3 0	+ 2 8
20	34 4	37 3	35 8	36 6	40 0	38 3	+ 2 2	+ 2 7	+ 2 5
25	31 2	34 0	32 6	32 7	36.0	34 3	+ 1 5	+ 2 0	+ 1 7
30	28 2	31.0	29 6	28.9	32 1	30 5	+ 0 7	+ 1 1	+ 0 9
35	25 3	28 1	26 7	25 4	28 4	26 9	+ 0 1	+ 0 3	+ 0 2
40	22 5	25 2	23 9	22 1	24 7	23 4	− 0 4	+ 0 5	− 0 5
45	19 8	22 4	21 1	18 9	21 1	20 0	− 0 9	− 1 1	− 1.1
50	17 2	19 4	18 3	15 9	17 7	16 8	− 1 3	− 1 7	− 1 5
55	14 5	16 4	15 4	13 2	14 6	13 9	− 1 3	− 1 8	− 1 5
60	12 2	13.8	13 0	10 8	11 8	11 3	− 1 4	− 2 0	− 1.7
65	9 9	11 2	10 5	8 8	9 4	9 1	− 1 1	− 1 8	− 1 4
70	8 5	9 3	8 9	6 9	7 5	7 2	− 1 6	− 1 8	− 1 7
75	7 1	7 5	7 3	5 3	5 7	5 5	− 1 8	− 1 8	− 1 8
80	6 2	6 5	6 4	4 1	4 5	4 3	− 2 1	− 2 0	− 2 1
85+	5 4	5 5	5 5	2 0	2 4	2 2	− 3 4	− 3 1	− 3 3
Balance							+24 8 −15 3 + 9 5	+28 7 −17 6 +11 1	+26 6 −16 6 +10 0

[1] See State Sanıtation, Vol. II, p. 300, by G. C. Whipple.

United States life tables. — In 1916 the Bureau of the Census published a special report entitled United States Life Tables, 1910, prepared under the direction of Prof. James W. Glover of the University of Michigan. This was the first report of its kind in America. The tables are based on the general unselected population, and, therefore, differ from the life tables of the insurance companies. The radix is 100,000 at age 0. The data were obtained from the U. S. Census of 1910. Expectations of life were computed by months up to one year of age, and after that by years up to age 106. Separate tables were given for males, for females and for both sexes combined; there were separate tables also for negroes and whites, and for native and foreign born whites; for cities and for rural districts, — all of these relating to the population of the original registration states, namely, the New England states, New York, New Jersey, Indiana, Michigan and the District of Columbia. Separate tables for males and for females were given for the states of Indiana, Massachusetts, Michigan, New Jersey and New York.

These tables are well prepared and their results are of much interest. Besides giving the expectations of life computed in the usual way, computations are made on the assumption of a stationary population, that is one where the general death-rate is equal to the general birth-rate. These have the advantage of excluding the effect of emigration results and immigration, and from them one can compare the death-rates of different communities for the population above a given age. For these results the reader is referred to the original report.

A few comparisons. — It will be interesting to make a few comparisons of the expectations of life at certain ages for different classes of people and at different ages. For greater details the reader should consult Professor Glover's report.

TABLE 158

EXPECTATIONS OF LIFE, 1910

Age Original registration states.	0	10	20	30	40	50	70
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Native white males..	50 58	51 93	43 32	35 61	28 33	21 20	9 09
Native white females . ..	54 19	54 43	45 76	37 98	30 33	22 78	9 80
Foreign-born white males	.	50 30	41 75	33 71	26 03	19 08	8 40
Foreign-born white females		52 24	43 50	35 31	27 55	20 09	8 67
Negro males	34 05	40 65	33 46	27 33	21 57	16 21	8 00
Negro females.	37 67	42 84	36 14	29 61	23 34	17 65	9 22
White males in cities . .	47.32	49 13	40 51	32.61	25 32	18 59	8 14
White males in rural part...	55 06	54 53	45 92	38 10	30 20	22 43	9 36
White females in cities. .	51 39	52 22	43 51	35 52	27 88	20 53	8 99
White females in rural part.	57.35	55 54	46 86	39 05	31 15	23 27	9 76
Males in Indiana	54 70	53 91	45 44	37.76	29 99	22 38	9.29
Males in Michigan. . . .	53 86	54 09	45 57	37 76	29 81	22 10	9 17
Males in Massachusetts.	49 33	51 14	42 48	34 55	26 97	19 79	8 58
Males in New Jersey	49 08	50 31	41 66	33 86	26 57	19 67	8 65
Males in New York.... ...	47.89	49 40	40.79	33 01	25 88	19 28	8 58

The greater longevity of females as compared with males is evident throughout the tables. It is greater for native whites than for foreign born whites, greater for whites than for negroes, greater for rural districts than for cities. The differences between the states depend upon differences in the composition of the population, and upon urban and rural conditions.

It is interesting also to compare the specific death-rates for the corresponding ages. The relations between these and the expectations of life are in a general way reciprocal. The specific death-rates are lower in the rural districts than in the cities, especially in the early and the later years; in middle life there is less difference. The differences between whites and negroes are very striking.

TABLE 159

SPECIFIC DEATH-RATES

Age Registration area.	0	10	20	30	40	50	70
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Native white males.... ..	126 02	2 37	4 82	7 14	10 02	21 20	57 20
Native white females ...	104 60	2 06	4 40	6 13	7 76	11 68	50 24
Foreign-born white males..	....	2 47	5 10	5 80	10 53	17.92	70 79
Foreign-born white females.		2 09	3 65	5 84	8 55	14 42	67 87
Negro males	219.35	5 02	11 96	14 96	21.03	31 42	83 98
Negro females...	185 07	5 18	10 74	12 02	17 50	25 52	71 27
White males in cities . .	133 80	2 59	4 93	7 22	12 10	19 17	74 20
White males in rural part.	103 26	2 07	4 83	5 39	7 06	10 65	52 93
White females in cities.	111 23	2 23	4 10	6 33	8 83	14 44	63.50
White females in rural part	84 97	1 80	4 41	5 46	6 65	9 91	49.92

Antidote for morbidness. — The constant study of statistics of disease and death tends to give some people an unwholesome view of life and causes them to devote too much attention to human ills. It is recommended that as an antidote for this morbidness the specific death-rate curve of morbidity, Fig. 67, be studied in reverse, as shown in Fig. 88. This indicates that throughout a person's life until old age approaches the chance of living is far greater than that of dying. Dr. Raymond Pearl has shown that the extent to which humanity drops by the wayside during the course of life is dependent chiefly upon biological laws and can be modified only slightly by our public health activities. Let the student who is interested plot the figures in Column 2 of Table 155, or better plot similar figures from Glover's U. S. Life Tables, which begin at birth instead of age ten. He will get a characteristic curve which, Dr. Pearl says, is similar to one he has obtained for flies, except that in the case of flies there is no infant mortality factor.

We ought not to spend too much time and thought and effort to keep ourselves from dying but should give far more attention than we do to living useful and happy lives. The

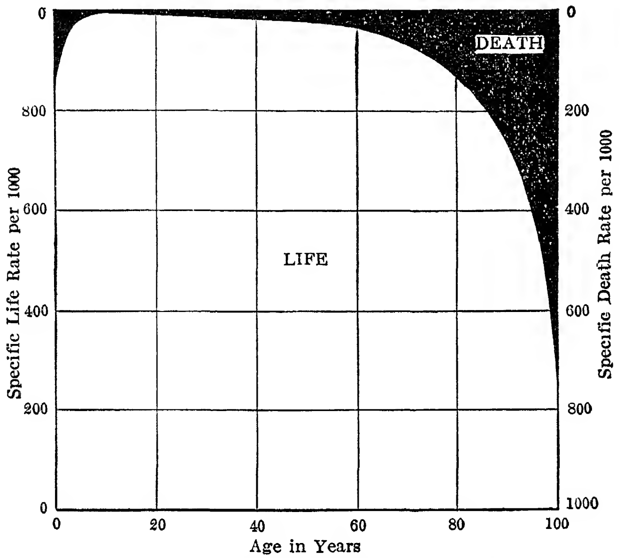


FIG. 88. — Specific Life-rates and Death-rates at different ages.

best philosophical principle is not to try to stay alive but to live while we are alive; to " work while it is day, for the night cometh."

EXERCISES AND QUESTIONS

1. Compare the life table for New Haven with that for the U. S. Registration Area. [See Am. J. P. H., Aug., 1918, p. 580.]

2. Compute a life table for some city, to be assigned by the instructor.

3. Find your own "probability of living a year," "vie probable." "most probable life-time," and "expectation of life."

CHAPTER XVI

A COMMENCEMENT CHAPTER

This last chapter is to be something like the day after college commencement. On the day before, the student regards his work as finished; his exercises are all completed, he has passed his examinations, he is to be graduated. But on the day after commencement he finds himself plunging into a world of problems yet unsolved; he sees that most of the things he is called upon to do were not in his curriculum; that he must learn to do these things for himself. Little by little he comes to realize that what his stupid old professors had been trying to do was not to tell him all there was to know in the world but to teach him how to think and how to use tools. He had heard much of principles, and laws and formulæ and synopses and all that, and had regarded them as the dry parts of his courses — the necessary evils. But little by little he finds that these general principles, these almost self-evident ideas, help him to solve his problems; that his systematic methods of going at a thing help him to do his work more easily and quickly; that by following the dry old laws of logic, his conclusions are somehow better than those of the other fellow who does not take the trouble to see that all the steps in the problem are "necessary and sufficient." In short, he comes to realize that his education has enabled him to do his work easier and better and has given him intellectual confidence. If it doesn't do this for him he has wasted his opportunities in college.

In the preceding chapters of this book the author has endeavored to place the emphasis not on the subject matter but on methods of procedure, to outline the simpler principles of the statistical method as applied to studies in demography, to warn against the common fallacies which so often creep into discussions of vital statistics, and to urge students and health officers not to be content with such things as general rates but to seek the answers to their problems by methods of statistical analysis and the use of specific rates and ratios.

Let us now take an outlook upon some of the problems of demography as they come piling in upon the health officer from day to day. And if, for convenience' sake, we take them at random, one after the other, without order or system we shall simulate more nearly every-day practice. If we can solve this and that problem or if we can see the steps in the solution we shall know that we have acquired the use of the tools of the statistician, and will have confidence in our own studies. This chapter will also include certain subjects which have not logically found a place in the preceding chapters. Several of these subjects might easily be expanded into chapters of their own.

Military statistics. — In general the vital statistics of armies are computed in the same way as those of civil populations, but instead of using the mid-year estimated population, the mean strength for the year is used as a basis of rates. An army does not increase in numbers as a population grows, slowly by geometrical progression, but is kept up to a fairly constant strength or is suddenly increased or decreased according to demands made upon it. An army represents a selected population, — males between certain age limits, and above set standards of health and physique. Rates computed for armies are therefore specific rates and they must not be compared with general rates. The health of the soldiers is carefully looked after by the surgeons, who are obliged to keep records; hence the morbidity records are more complete than in the case of the civil population.

Since 1894, when an international commission for the unification of medical statistics met at Budapest, tables of statistics made up according to certain schedules have been published for most armies. These may be found in the annual reports of the Surgeon General of the U. S. A. In the report for 1916 we find that in the entire U. S. army of 93,262 enlisted men in 1915 the sick admissions "to quarters" and "to hospitals" amounted to 745 per 1000. This does not mean 745 different men, for sometimes the same man was admitted more than once. Of these 96 per cent returned to duty, *i.e.* recovered, 0.65 per cent died, and 3.4 per cent were "otherwise disposed of." The death-rate for the mean strength was 4.6 per 1000. The annual number of days lost through sickness was 9.44 for each soldier, or 12.7 for each "admission." In the published tables the figures are classified according to the location of the troups, the arms of the service, the season, the larger garrisons, and according to the cause of the sickness or death. It should be observed that in the international tables for the army the international list of diseases, as given on page 257, is not followed. The Surgeon General of the United States uses it, however, in the body of his report.

In 1915 in the entire U. S. army (103,842 officers and enlisted men) the following were the rates per 1000 of mean strength:

TABLE 160

VITAL STATISTICS OF U. S. ARMY: 1915

	Rates		
	From disease.	From injury.	Total.
(1)	(2)	(3)	(4)
Admissions	597 0	129.2	726 2
Discharged on certificate of disability.	12 6	1 4	14 0
Died.	2 5	1 9	4.4
Total losses.	15 1	3 3	18 4

The percentage of soldiers constantly non-effective was 2.5 per cent.

If we look back a few years we find that the health of the army has been improving.

TABLE 161

HOSPITAL ADMISSION RATES AND PERCENTAGE OF NON-EFFECTIVES, U. S. A.

Year.	Admission-rate per 1000	Non-effectives, per cent.
(1)	(2)	(3)
1906	1118	4 8
1907	1102	4 4
1908	1079	4 2
1909	964	4 1
1910	870	3 5
1911	858	3.2
1912	806	2 9
1913	666	2 4
1914	660	2.4
1915	726	2 5
1916	597	2 5

Army diseases. — In the consideration of army diseases one must distinguish between peace times and war times; one must also distinguish between the diseases which cause death and those which render the men non-effective.

In 1915 the specific death-rates among the American enlisted men in the U. S. A. were, in order of their importance, as follows:

	Per 100,000
Tuberculosis	33
Pneumonia (lobar)	31
Organic heart disease	23
Measles	23
Appendicitis	13
Epidemic cerebro-spinal meningitis	11

The principal causes of discharge were:

	Per 1000
Mental alienation	3.30
Tuberculosis	1.79
Flat foot	1.25
Venereal disease	0.82
Epilepsy	0.69
Organic heart disease	0.50

The admission and non-effective rates for white enlisted men were:

TABLE 162

ADMISSION RATES AND PERCENTAGE OF NON-EFFECTIVES FROM PARTICULAR DISEASES, U. S. A.

	Admission rate, per 1000	Non-effectives, per cent
(1)	(2)	(3)
Venereal diseases	106	0 47
Tuberculosis	3	0 17
Mental alienation	4	0 09
Bronchitis	35	0 06
Tonsilitis	47	0 07
Appendicitis	9	0 06
Malaria	24	0 05
Mumps	10	0 05
Influenza	35	0 05
Diarrhœa and enteritis	32	0 04
Measles	7	0 05
Articular rheumatism	6	0 04
Hernia	4	0 04

In war times we have to consider the venereal diseases, syphilis, gonorrhœa, etc.; the diarrhœal diseases, typhoid fever, cholera, dysentery; the insect-borne diseases, typhus fever, relapsing fever, trench fever, malaria, etc.; scurvy — besides all sorts of diseases associated with wounds. No attempt will be made here to discuss these war diseases, because the Great War will yield statistics better and more complete than any which we now have. Some day it will be in order to make comparisons between the Civil war, the Spanish war and the present Great War. We shall then see what enormous strides have been taken in sanitation, in the use of antitoxins, in providing proper food, in the enforcement of the rules of personal hygiene, in the treatment of the sick and wounded, in the ambulance and hospital service, in the protection of the health of the civil population in war time in factory and home. One gratifying result of the war seems assured — a world-wide up-lift in public health. We shall hereafter need world-wide vital statistics, that is, we shall need the science of demography.

Effect of the Great War on demography. — A thousand and one questions have arisen as a result of the war.

What effect did the war have on the marriage-rates, birth-rates and death-rates? A big hole was made in the male population for the ages of youth and early manhood; fewer young men of twenty in 1920 will mean fewer men of thirty in 1930 and fewer men of forty in 1940. How will this alter the general death-rate? Will the birth-rate rise as a natural reaction to war's destruction or will hard economic conditions keep it low? Can we learn anything from past wars on this matter?

Typhoid fever, the past scourge of armies, has been almost completely conquered. Will the venereal diseases also be conquered? Will the Great War point out the way to this end? And what about tuberculosis, the scourge of Europe? Will typhus fever and enteric fever move westward from Eastern Europe over the west?

What has been the effect of reduced food rations on health and physique? Will the loss of the most vigorous young men lower the standards of physique by hereditary influences?

Will the lessons in hygiene and sanitation be so well learned that their benefits will offset other baneful influences of the war?

We knew approximately the standing of the nations before the war as to population, natural rates of growth, migrations, death-rates, and so on — how will these nations stand after the war? Who will be the greatest losers? What will be their most serious losses?

Such questions as these will force themselves upon us for many years. Demography will be the science looked to for the answers.

Hospital statistics. — There are many hospitals in the country and they are an increasingly important factor in the control of disease. Some of these hospitals keep good records of their cases and some publish them. Other hospitals keep very inadequate records and publish nothing. Uniformity in this matter is most desirable, as a good opportunity for collecting facts relating to certain non-reportable diseases and valuable data which would show their fatality are being lost. Adequate records of diagnosis, methods of treatment and results would help greatly in appraising the value of medical practice and in improving the efficiency of the hospitals themselves.

Several plans for unifying hospital statistics have been suggested. Dr. Charles F. Bolduan,[1] of the New York City Health Department, suggested the idea of a uniform discharge certificate, to be filled out for each case on leaving a hospital, and filed with the local health authority — a certificate comparable to the ordinary death certificate. Another method is to have the annual reports (or monthly reports) made out on some fixed schedule of statistics and submitted to some central authority.[2] Perhaps the U. S. Public Health Service may some day take the lead in the collection of the important data to be secured from hospitals.

Pearl has given the following list of items which should be included in a hospital case record: —

1. Case number.
2. Service number.
3. The patient's name.
4. Diagnosis.
5. Sex.

[1] N. Y. Medical Journal, Mar. 29, 1913. See also page 471.

[2] Amer. Jour. Pub. Health, Apr., 1918.

6. Social status (single, married, widowed, divorced).
7. Age.
8. Occupation.
9. Body weight.
10. Stature.
11. Race.
12. Birthplace.
13. Service under which patient was treated.
14. Date of admission to hospital.
15. Duration of stay in hospital.
16. Time from onset of diagnosed condition to admission to hospital.
17. Condition at admission.
18. General health of patient prior to present illness.
19. Whether there is any family history of the diagnosed disease.
20. Whether a first entry or a readmission.
21. Whether a free, a paying, or a part-paying case.
22. Condition at discharge.
23. Whether or not an autopsy was performed.
24. Autopsy number, if any.
25. Nature of treatment.
26. Complicating pathological conditions, additional to the one diagnosed.

Statistics of industrial disease. — Statistical studies of industrial diseases are becoming increasingly numerous. It is a most complex and difficult branch of the subject. At the outset we are met with the fundamental difficulty of defining occupations. The extent of this difficulty may be appreciated from the fact that in 1915 the U. S. Bureau of the Census published an "Index to Occupations" which covered over four hundred pages and included 9000 occupational designations. The report makes 215 main classes, 84 of which are subdivided. This list has been given in Chapter IX.

A second difficulty is due to the migration of laborers from place to place, and from one class to another. A third, which grows out of the other two, is the difficulty of getting constant, well-defined classes to serve as the basis of the computation of rates and ratios. A fourth is the oft repeated error of concealed classification. These and other minor difficulties have compelled us to resort to the use of specially gathered statistics, which are often not truly representative of the conditions discussed.

For example, the Massachusetts General Hospital recently made a study of lead poisoning in its Industrial Clinic. During the first year of this clinic 148 cases of lead poisoning were diagnosed in the hospital as against 147 during the previous five years.

This was found by sifting out of the hospital admissions by a trained worker those suspected of being exposed to special industrial hazard. A study of these 148 cases gave an industrial distribution as follows:

TABLE 163

Occupation.	Number exposed.	Number cases.	Per cent poisoned.
(1)	(2)	(3)	(4)
Painters	217	68	31
House	....	56	....
Others	....	12	....
Shipyard and navy yard	54	16	30
Rubber workers	169	11	7
Brass foundrymen	9	4	44
Lead and lead oxide worker	....	6	....
Plumbers	42	8	19
Printers	64	11	17
Miscellaneous	135	14	10
Non-industrial	....	10	....
Total	....	148	....

An attempt to ascertain the rate of attack was made by ascertaining as well as possible the number of persons exposed. These rates are, of course, far too high; 31 per cent of all painters did not get lead poisoning, but only 31 per cent of the exposed persons who were sorted out in this industrial clinic. The report does not err in this respect but the reader may get a false impression unless he reads thoughtfully. The underlying idea of this clinic is excellent and the work, interrupted during the war, has already yielded excellent results. The danger of lead poisoning of men engaged in certain occupations in ship-yards has been clearly shown.

Economic conditions and health. — Poverty and disease mutually influence each other. We cannot expect to solve the problem by attacking either alone. It is most difficult to separate cause from effect. In fact, there is a third major factor which we may call ignorance — and all three are mutually dependent. Then there are many minor factors.

We can correlate these things by statistics, and that is worth while because it calls attention to the problems; but the plan of attack must rest upon the fact that the different conditions are mutually related. If we help only a little to raise the economic and hygienic conditions the result is an accelerating social advance; to aid one without the other does not bring about permanent betterment.

A glimpse at these mutual relations, as shown by Warren and Sydenstricker,[1] is instructive. They classified the health of certain garment workers with respect to the annual earnings of the heads of families as follows:

[1] Pub. Health Reports, May 26, 1916, p. 1298.

TABLE 164

HEALTH OF GARMENT WORKERS

	Annual earnings.		
	$500	$500-$699	$700
(1)	(2)	(3)	(4)
Number of persons	381	581	462
Ave. annual earnings	$382	$577	$866
Ave. rate of weekly earnings	$19	$23	$27
Per cent which actual earnings were of maximum possible earnings	38%	48%	61%
Maximum possible earnings for year	$988	$1196	$1404
Ave. number of persons per family	5.36	5 38	4 88
Ave. number of children born per family	3 78	3 34	2 75
Ave. number of children living per family	2 99	2 78	2 43
Ave. number of children dead per family	0 78	0 56	0 32
Infant mortality rate	206 9	167.2	116 5
Per cent of male married garment workers who were poorly nourished	25 00	15 02	12 72
Ave. hæmoglobin index, Talquist	85 94	86 99	87 35
Per cent with hæmoglobin index under 80	9 94	5 65	4 42
Per cent of family heads tuberculous.	5 64	5.30	0 44

Accidents and accident-rates. — Injuries and deaths from accidental causes are attracting much attention nowadays, and rightly so. The death-rate from accidents in the United States is far greater than from typhoid fever. Only a few years ago it was more than 100 per 100,000 of population. Some of the principal causes are automobile and railroad accidents, falls, drowning and burns, but there are many accidents associated with different industries. All of these present interesting problems for study and each should be studied by itself.

Taking accidents as a general class, we find that the specific death-rates follow closely the death-rates from all causes, decreasing from the first year to a minimum between ages 10–14 and then increasing steadily to the highest ages. Owing to the age distribution of population we find the mode of the accident distribution curve occurring somewhere in age group 25–29 years.

In the case of railroad accidents among males the mode is found in age-group 25–29 years, that is, the largest number of accidents occurs among males at that period; in the case of falls the mode is in age-group 45–49; in the case of drowning it is at age 20–24. The specific death-rate from railroad accidents is low until the age of twenty, when it rises to above 30 per 100,000 and fluctuates between 30 and 50 for all higher age-groups. The specific death-rate from falls rises steadily from the tenth year and above 75 years of age exceeds 100 per 100,000. The specific death-rate from drowning on the other hand is highest at about twenty years of age. Except for falls the accident-rates from the major causes are higher for males than for females.

If time permitted it would be interesting to follow up this subject of accidents and find the seasonal distribution and classify them in other ways.

In studying accidents in industrial establishments we must ask the usual questions, — where, when, what, how, who, and answer them by collecting the necessary statistics. It does not do to follow popular impressions in these matters. Thus it is sometimes said that most accidents occur "at the end of a tired day," yet statistics collected in Massachusetts by the Industrial Accident Board showed that it is between 9 and 10 A.M. and 2 and 3 P.M. that accidents are most frequent. Yet this general statement is not enough. We need to know what kinds of accidents are meant. Perhaps some kinds of accidents do occur at the end of the working day. Then there are daily differences to be considered, and seasonal differences, as well as differences due to the weather. In the case of the English munition factories, which run night and day, the accident mode occurs in the evening. One runs a great risk in generalizing from composite statistics.

There are various ways of expressing accident rates. One is the ratio between annual accidents and number of employees. Another is between annual accidents and the number of full time workers, *i.e.*, 300 days per year. Another is between days lost through accident and full time workers. Differences in the severity of the accidents are also important from an economic point of view.

Age distribution of cases of poliomyelitis. — One of the diseases which has recently attracted attention is Anterior Poliomyelitis, commonly known as infantile paralysis. Many attempts have been made to correlate the occurrences of this disease with factors which might point to the manner of its communicability. There is an excellent opportunity here for original statistical work based on recently accumulated data. As bearing on the theory of contact as a major element in its communicability the age distribution of the cases is important. The disease is essentially one of the early ages. A recent study by the author appears to indicate that the median age is inversely proportional to the density of population. This is likewise true for measles, whooping cough and similar diseases.

It has been noticed that if the cases of poliomyelitis are plotted on logarithmic probability paper they tend to fall on a straight line, except that above the upper decentile there is an irregular divergence from the straight line. From this diagram it is easy to read off the median age or the per cent of cases below any age or between given ages. Fig. 89 shows that in the populous city of New York the median age was 2.5 years, in Boston 3.7 years,

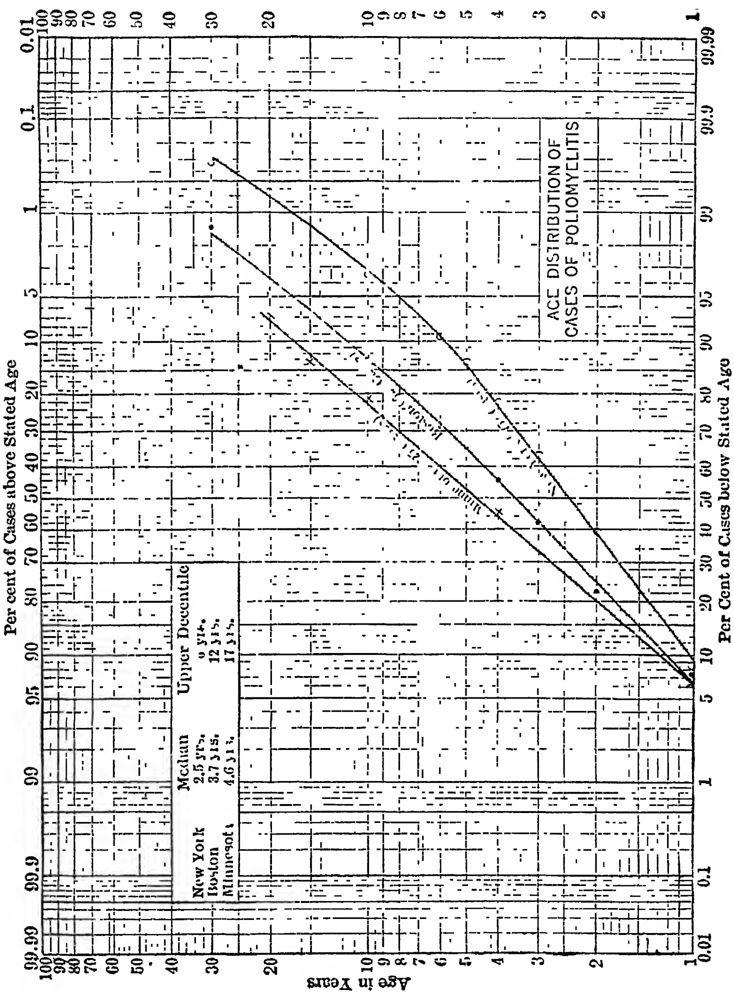


FIG. 89. — Example of Plotting on Logarithmic Probability Paper.

and in Minnesota 4.6 years. Similar differences were observed in the upper decentiles. These data are not strictly comparable as they were not for the same year and are presented merely to show the advantage of this method of plotting. It is interesting to note that scarlet fever cases plotted by ages on logarithmic probability paper also fall nearly on a straight line.

The Mills-Reincke Phenomenon. — Problems like this offer excellent opportunities to apply the principles of statistics. In 1893–94 Mr. Hiram F. Mills found that at Lawrence, Mass., after the introduction of the sand filter to purify the public water-supply taken from the polluted Merrimac River, there was a material reduction in the general death-rate of the city. Notably typhoid fever was reduced, but this reduction was not sufficient to account for the fall in the general death-rate. About the same time Dr. J. J. Reincke found the same thing in Hamburg. In 1904 Hazen studied these and other records and stated that "where one death from typhoid fever had been avoided by the use of better water, a certain number of deaths, probably two or three, from other causes have been avoided." In 1910 Sedgwick and MacNutt[1] published an elaborate study in which Hazen's statement was dignified with the rank of "theorem."

The natural inference from such statements is that the purification of a polluted water-supply reduces deaths from causes other than typhoid fever. In Lawrence if one considers short periods before and after the introduction of the filter a decrease is observed in several diseases, — as, for example, pneumonia, tuberculosis, cholera infantum and so on. Some have, without sufficient thought, extended the

[1] Sedgwick, W. T. and J. Scott MacNutt. On the Mills-Reincke Phenomenon and Hazen's Theorem. Jour. Infectious Diseases, Aug., 1910, pp. 489–564.

Fink, E. B., American Mortality Statistics and the Mills-Reincke Phenomenon. Jour. Infectious Diseases, July 1917, pp. 62–94.

idea back of Hazen's "theorem" to undue limits, and have argued that pure water has the effect of raising the general health, of lifting the health tone of individuals, and so has a value beyond that of preventing the spread of diseases of the intestinal tract. This is unwarranted and to that extent Dr. Chapin[1] and others have rightly criticized the "theorem." The idea underlying the theorem may be correct, but the vital statistics available do not demonstrate it. The correlation between the decreased typhoid-fever rate and the general death-rate in cities which have introduced water filtration or otherwise bettered their supply is not high. It is more frequently true where the original water-supply has been very badly polluted, as was the case at Lawrence. Even at Lawrence it is probable that the pneumonia death-rate was abnormally high just before the filter was built and that the reason for its subsequent decrease had little or nothing to do with water filtration. Yet to condemn the "theorem" altogether is to take too extreme a view. Without doubt infant mortality was reduced by filtration, chiefly through the reduction in diarrhœal diseases. McLaughlin has shown that this has occurred in many places.

The trouble with this whole problem has grown out of the use of general rates. If we want to find the effect of filtration we must compare the morbidity and mortality rates for particular diseases before and after filtration, with due regard to changes in population. Somebody who has time ought to restudy this whole matter in the light of recent data.

The sanitary index. — Many attempts have been made to devise a "sanitary index," to select and combine certain specific death-rates so as to get for a given place a single figure which, when compared with similar figures for other places, will correlate health and sanitary conditions. We

[1] Chapin, Chas. V., "Modes of Infection."

know that the general death-rate will not serve this purpose. Even the death-rate adjusted to a standard population is inadequate. The infant mortality has been claimed as the best index. Dr. Wilmer R. Batt,[1] the Registrar of the Pennsylvania State Department of Health, has suggested a composite index which illustrates this striving to get an index. It is computed as follows:

$$\text{Sanitary index} = \frac{\text{Deaths from causes No. 1 to No. 17 plus all infant deaths}}{\text{Population}}.$$

The ratio of all the other deaths to the population is called the residual death-rate. Hence the sum of the two gives the general death-rate.

He found that from 1906 to 1915 the general death-rate of the state declined from 16.0 to 13.8 per 1000 *i.e.*, 13.8 per cent. The "sanitary index," however, declined from 6.5 to 4.5, or 30.8 per cent, while the residual death-rate declined from 9.5 to 9.3 or only 2.1 per cent. This index, it will be observed, takes no account of the changing composition of the population.

Others have suggested that the index ought to be based on social and economic factors as well as vital statistics, and their point seems to be well taken. This only emphasizes the complexity of the problem. The author believes that it is too early to attempt the establishment of a health index, and that better results will be secured by the critical use of specific rates.

Current use of vital statistics. — Vital statistics have their historic uses, but their greatest value lies in their immediate use. It is interesting and ultimately most valuable to know that a baby has been born at a certain place, on a certain day, of such and such parentage, but it is more

[1] Penn. Monthly Health Bulletin, No. 70, Feb., 1916.

important that the baby shall live and grow up well. No baby should be allowed to come unnoticed into the world; boards of health or other proper authorities should see to it that every baby born has a good chance to live. In most cases the parents, the physician and the nurse are sufficient caretakers and the public authorities should not be unnecessarily intrusive or over-zealous; on the other hand their advice and aid should be prompt where occasion warrants, and immediate knowledge of the facts is the only basis of wise action.

In reported cases of diseases dangerous to the public health the need for prompt action is even greater. It is by the daily study of such reports that pending epidemics or local outbreaks of disease may be headed off. Every local health officer should keep on the walls of his office, or on a suitable frame, or in shallow drawers, a series of local maps — one for each important communicable disease. The maps should show the names of the streets. There should be a street index at hand, with the street numbers given for each intersection, and with information as to which side of the street has the odd (or even) numbers. On these maps, with the aid of the index, each case of communicable disease should be marked with a pin immediately on receipt of the report. There are many little devices involving the use of pins of different colors for different dates, the removal of pins after recovery, the additions of pins to indicate death, and so on; the details of which are bound to vary according to local conditions. But the main thing is to study the pins *daily*. In the case of state departments of health the required maps are of course on a different scale and the cases are arranged by cities and towns instead of streets. Both local and state studies are necessary.

In addition to the location maps the health officer needs to keep up chronological charts for each disease — a separate chart for each. Pins may be used for this work also, or lines may be drawn, black or colored. These charts, together with the maps, answer the questions *where* and *when* did the cases occur.

For state work another device is convenient, — namely, a summary of cases by cities, towns, or other geographical divisions, and by weeks or months. These should be made up regularly for comparison with past records. All cities have certain numbers of cases of communicable diseases which occur with a fair degree of regularity — and what the health officer needs most to know is whether there is at any time an abnormally large number of cases of any disease. In order to quickly tell this he needs to have at hand certain generalized results of past experience. In New York City Dr. Bolduan was in the habit of finding the average number of cases of typhoid fever, for example, in each ward and for each week of the year, — but omits from these averages any local outbreak or epidemics. He has called this the "normalized average."[1] In the author's opinion what is needed here is not the average, with the unusual conditions omitted, but the median. The Massachusetts State Department of Public Health is using the median under the name *endemic median.* This can be very easily found for a five- or ten-year period and serves admirably as a standard of comparison. Of course it needs occasional revision.

Card systems are generally found most convenient for keeping records of individual reports, and the punched-card system with mechanical devices for sorting and counting is the best of all.

[1] Bolduan, Chas. F., Typhoid Fever in New York City, No. 3 Monograph Series, Aug., 1912.

Publication of reports. — The author will perhaps be regarded as a heretic on the subject of published reports. He believes, however, that thousands of pages of useless tables of reported cases of disease are printed every year in the United States at enormous expense and that the same amount of money spent in maintaining more complete and more accurate records in state and local health departments and in studying and using the records from day to day would bring better results. The object of reporting diseases dangerous to the public health is not to pile up records but to prevent the diseases from spreading. Statements of the occurrences of communicable diseases published monthly, or even weekly, usually reach their readers too late to be of any practical use, while as historical records such frequent publication is wholly unnecessary. Some publication is desirable, however, but only that which is of real use.

Let us consider the case of communicable diseases, for example, as reported to a state department of health. If the number of cases of measles in a city is less than the endemic median, that is, less than the ordinary number of cases, no announcement is necessary; but should the number of cases rise above the endemic median a prompt announcement of that fact in the local paper [1] might be of positive benefit as it would sound a warning. If the fire bells were ringing very gently all the time except when a fire occurred and then rang loudly, the public would not heed the warning; and in the same way the constant publication of figures which are of little moment blunts the sense of caution. Arrangements might well be made, however, for the immediate publication of notices of all unusual occurrences of disease in local papers or wherever such notices would do the most good. So far as communicable

[1] Daily paper preferred.

diseases are concerned the general principle of publication should be to publish at once or not at all and to publish only the unusual occurrences. The preparation of such notices would by reflex action stimulate the health officers themselves, and would assist physicians in making diagnosis of suspected cases.

The problem of annual reports is different. Here the object is to establish a record for permanent preservation, useful alike to health officers, to physicians, and to the interested public. The calendar year with its subdivisions is the most convenient unit of time. The vital statistics of every political subdivision in the country should be published annually, and as soon after the end of the year as possible. Here we find a great amount of unnecessary duplication. It is a waste of money to have the local Board of Health of Cambridge, Mass., publish certain facts (usually a year or two late), to have the same facts published by the State Registrar and perhaps by the State Department of Health, and finally to have them published again by the U. S. Bureau of the Census, and perhaps by the U. S. Public Health Service. It is worse than wasteful, because the various tables often fail to agree and all sorts of distressing statistical errors creep in. On the other hand, while the figures for Cambridge may be found in several places, there may be other places where it is difficult to find any statistics at all. Uniformity in this matter is very greatly needed, and this must come through federal control or state coöperation, with uniform minimum schedules to serve as a basis of record.

The author believes that no systematic attempt should be made every year to publish specific rates or minute analyses of rates, for the reason that such studies are based necessarily on estimated populations. Such studies are of course very necessary for the study of special problems as they arise, but these results should be published as special studies and not as a part of a systematic schedule. It would be better to wait for the census years, when the *facts* of population can be used instead of *estimates* and to then make a most careful analysis of all vital statistics. Such an analysis made once in five years in Massachusetts would serve every useful purpose, would save much time and expense, would avoid the need of revision and would prevent the publication of figures which contain annoying variations. The principle should be to wait for the facts, and then make a careful analysis based on the facts. Of course, general rates should be published annually, based on estimated populations, but no one need take these very seriously, as in any event they mean little. If it is thought worth while to publish specific rates for each post censal year, these should be recomputed after the next census has been taken.

Various attempts to establish standards have been made. One of these may be found in the American Journal of Public Health.[1] Another in the annual report of the N. Y. State Department of Health for 1912, another in the Quarterly Publication of the American Statistical Association[2] and so on. In establishing standards it will be necessary to determine what shall be the geographical units, what subdivision of the year, what data and in what combinations. The usual facts secured in regard to deaths are (1) place of death, (2) time of death, (3) sex, (4) age, (5) race or color, (6) cause of death, (7) birthplace, (8) birthplace of father, (9) birthplace of mother, (10) marital condition, (11) occupation. The possible number of combinations of these eleven items two at a time is 55, three at a time 165, and four at a time 330. No wonder therefore that there is lack of uniformity in published reports. Any

[1] 1913, p. 595. [2] 1911, p. 510.

standard tables must of necessity be arbitrary. The time has come when uniformity of report is necessary in the interest of both economy and efficiency.

Need of international standards. — Anyone who attempts to make comparative studies of the vital statistics of different countries soon finds himself handicapped because of the lack of uniformity of the classifications used in the published tables of data. Different age-groups are used in different countries, and even in the same country, in the United States for example, the same age grouping is not always used for population and for deaths. In France no sex division is made in the death statistics, and the terms urban and rural are loosely used. In several countries where the international list of the causes of death is used, the published tables are based on an abridged list rather than the standard list.

Several modes of procedure for improving this situation have been suggested. It would appear that the authority which ought to take the lead in bringing order out of confusion is the Division of Public Health of the League of Nations, or in case of no action by this body the next International Congress called to revise the International List of the Causes of Death in 1929.

EXERCISES AND QUESTIONS

1. Distinguish between the environments represented by the following terms:

a. A felt hat and a straw hat factory.
b. A paper box and a wooden box factory.
c. An iron and a brass foundry.
d. A wholesale and a retail merchant or dealer.
e. A farm laborer on his home farm and one working out.
f. A clerk in a store and a salesman.
g. A dressmaker in a factory or shop and one working elsewhere.

h. A cook and a servant.
i. A paid housekeeper and a servant girl.
j. A practical and a trained nurse.

2. To what extent do these terms conceal other important differences in age or sex or nationality?

3. What data were collected in the industrial clinic of the Massachusetts General Hospital? [Monthly Review (Dec., 1917), U. S. Bureau of Labor Statistics. Edsall, David J.: The Study of Occupational Diseases in Hospitals.]

4. How would you explain the alleged fact that more cases of infectious diseases are reported to the New York City Department of Health on Monday than on any other day, and the fewest on Saturday?

5. How are the medical and vital statistics of the U. S. Navy kept? [See Am. J. P. H., June, 1918, p. 442.]

6. How are the medical and vital statistics of the U. S. army kept? [See Am. J. P. H., Jan., 1918, p. 14.]

7. What facts are needed in the registration of still-births? [See Am. J. P. H., Jan., 1917, p. 46.]

8. Describe the epidemic of poliomyelitis in New York and New England in 1916. [See Am. J. P. H., Feb., 1917, p. 117.]

9. What proportion of children "take" the common children's diseases at some time? [See Am. J. P. H., Sept., 1916, p. 971.]

APPENDIX I

REFERENCES

To study demography, or even vital statistics, seriously one must have at hand several of the standard textbooks on the statistical method, and certain of the more recent federal, state and municipal reports. One must also have access to files of certain periodicals. The following is a list of some of the more important of these references. It is far from being complete, and is intended merely to pave the way for further searches in the library.

A complete list of references to books and articles on the many phases of the subject would be overwhelming. The most recent writings on vital statistics are not necessarily the best for the beginner to study, as some of the soundest and most logical monographs were written many years ago. Of course, the most recent data are the most interesting — but that is another matter.

Many references to particular articles will be found scattered through the footnotes of this book and printed in connection with the Exercises and Questions.

GENERAL TEXTBOOKS.

NEWSHOLME, ARTHUR. Elements of Vital Statistics. Macmillan Co., 1899.

BOWLEY, ARTHUR L. Elements of Statistics. New York, Scribners, 1907.

BOWLEY, ARTHUR L. An Elementary Manual of Statistics. London, MacDonald and Evans, 1910.

ELDERTON, W. PALIN and ETHEL M. ELDERTON. Primer of Statistics. New York. Macmillan Co.

KING, WILLFORD I. The Elements of Statistical Method. New York, Macmillan Co., 1912.

ZIŻEC. Statistical Averages. New York, Henry Holt, 1913

TRASK, JOHN W. Vital Statistics — a report published by the U. S. Public Health Service, Apr 3, 1914.

YULE, G. UDNY. Introduction to the Theory of Statistics. London, Griffin & Co., 1912.

WHIPPLE, GEORGE C. Typhoid Fever. New York, John Wiley & Sons, Inc., 1908.

KOREN, JOHN. History of Statistics. New York, Macmillan Co., 1918.

PERIODICALS.

AMERICAN STATISTICAL ASSOCIATION. Quarterly Publications. Vol. I in 1888.

AMERICAN JOURNAL OF PUBLIC HEALTH. Monthly. The official publication of the American Public Health Association.

PUBLIC HEALTH REPORTS. Weekly. Published by the U. S. Public Health Service.

U. S. BUREAU OF LABOR STATISTICS. Monthly Review.

JOURNAL OF THE ROYAL STATISTICAL SOCIETY.

BIOMETRIKA. A Quarterly Journal. University of Chicago Press.

ANNUAL, MONTHLY AND WEEKLY REPORTS.

There are scores of annual reports which deal with vital statistics. The following are illustrative:

U. S. BUREAU OF THE CENSUS. Mortality Statistics. Annually since 1900.

ENGLAND AND WALES. Annual reports of Registrar-General. (79th report in 1916.)

MASSACHUSETTS STATE REGISTRATION REPORTS. Annually since 1842.

MASSACHUSETTS STATE BOARD OF HEALTH (now Department of Public Health). Annually since 1870.

STATE DEPARTMENTS OF HEALTH of New York, New Jersey, Pennsylvania, Ohio, Michigan, Maine, New Hampshire, Connecticut, etc.

ANNUAL REPORTS OF BOARDS OF HEALTH of New York City, Boston, Philadelphia, Chicago, Providence, etc.

Some boards of health publish monthly reports — New York, Massachusetts, Ohio, etc.

Some city health departments publish weekly reports — New York, Chicago, etc.

DEMOGRAPHY.

STATISTIQUE GÉNÉRALE DE LA FRANCE. Statistique Internationale du Mouvement de la Population d'après les registres d'état civil, 1907, 1913.

WESTERGAARD, HARALD. Die Lehre von der Mortalität und Morbilität, anthropologisch-statistische Untersuchungen. Jena. Gustav Fischer, 1901.

GRAUNT, CAPT. JOHN. Natural and Political Observations based upon Bills of Mortality. 1662. (Historical value.)

CHADWICK, EDWIN. Health of Nations. (Historical value.)

FARR, WILLIAM. Vital Statistics — a memorial volume of selections from his reports and writings. Edited by Noel A. Humphreys, London. Office of the Sanitary Institute.

MEITZEN, DR. AUGUST. History Theory and Technique of Statistics. Translated by Dr. Roland P. Falkner. Annals of the Am. Acad. of Political and Social Science, 1891.

PEARSON, KARL. Life, Letters and Labors of Sir Francis Galton, Vol. I. Cambridge, England, University Press, 1914.

BAILEY, WM. B. Modern Social Conditions. New York, Century Co., 1906.

PEARL, RAYMOND. The Vitality of the Peoples of America. Am. Jour. of Hygiene Vol. I, Nos. 5 and 6, 1921.

ARITHMETIC.

WEST, CARL S. Introduction to Mathematical Statistics. Columbus, R. G. Adams & Co., 1918.

BAILEY, W. B. and JOSEPH CUMMINGS. Statistics. Chicago, A. C. McClurg Co., 1917.

WESTERGAARD, HARALD. Scope and Methods of Statistics. Quar. Pub. Am. Sta. Asso., XV, 1916, pp. 225–291.

SECRIST, HORACE. Introduction to Statistical Methods. New York, Macmillan Co., 1917.

SAXELBY, F. M. A Course in Practical Mathematics. London, Longmans, Green & Co., 1908.

THOMPSON, SYLVANUS P. Calculus Made Easy. London, Macmillan Co., 1917.

GRAPHICS.

REINHARDT, CHAS. W. Lettering for Draftsmen, Engineers and Students. New York D. Van Nostrand Co., 1909.

PEDDLE, JOHN B. The Construction of Graphical Charts. New York, McGraw-Hill Co., 1910.

BRINTON, WILLARD C. Graphic Methods for Presenting Facts. New York, Engineering Magazine Co., 1914.

FISHER, IRVING. The Ratio Chart. Quar. Pub. Am. Sta. Asso., 1917, p. 577.

HASKELL, A. C. How to Make and Use Graphic Charts. New York, Codex Co., 1920.

MARSHALL, WILLIAM C. Graphical Methods for Schools, Colleges, Statisticians, Engineers and Executives, New York, McGraw-Hill Book Co., 1921.

CENSUS — REGISTRATION.

WILBUR, CRESSY L. The Federal Registration Service of the United States: its development, problems and defects. U. S. Bureau of the Census, 1916.

NEWSHOLME, ARTHUR. A National System of Notification and Registration. Jour. Royal. Sta. Soc., Vol. 59, p. 1, 1896.

DURAND, E. DANA. Changes in Census Methods for the Census of 1910. Am. Jour. of Sociology, 1910.

U. S. BUREAU OF THE CENSUS. American Census Taking from the First Census of the United States, 1908.

U. S. BUREAU OF THE CENSUS. Index to Occupations, alphabetical and classified, 1915.

POPULATION.

UNITED STATES CENSUS, 1790–1900. Comprehensive reports, usually in several volumes, published every ten years.

U. S. BUREAU OF THE CENSUS. 1910. Population, Vols. I, II and III.

U. S. BUREAU OF THE CENSUS Annual Estimates of Population, are published in a series of bulletins. Bulletin 133, for 1916.

U. S. BUREAU OF THE CENSUS. A century of Population Growth, 1790–1900. Pub. in 1909.

U. S. BUREAU OF THE CENSUS, 1920. Population, Vol. I. *et seq.*

MASSACHUSETTS STATE CENSUS. Intermediate between federal censuses since 1845. [Last published report in 1905; report for 1915 in preparation.]

LEROY-BEAULIEU, P. The Influence of Civilization on the Movement of Population. Jour. Royal Sta. Soc., Vol. 54, 1891.

FRANKLIN, BENJAMIN. Observations concerning the Increase of Mankind. Book, Philadelphia, 1751.

JARVIS, E. History of the Progress of Population of the United States. Book, Boston, 1877.

BAILEY, W. B. Modern Social Conditions. N. Y., Century Co., . 1906.

GENERAL-RATES.

NEWSHOLME, A. The Declining Birth-rate. New York, Moffat, Yard & Co., 1911.

U. S. BUREAU OF THE CENSUS. Birth Statistics. First annual report in 1915.

HUMPHREYS, N. A. Value of the Death-rate as a Test of Sanitary Conditions. Jour. Royal Statistical Society, Vol. 37, 1874.

YULE, G. U. On the Changes in the Marriage and Birth-rates in England and Wales during the past Half Century. Jour. Royal Sta. Soc., Vol. 69, p. 88, 1906.

SPECIFIC RATES.

PEARSON, KARL, ALICE LEE and ETHEL M. ELDERTON. On the Correction of Death-rates, 1910.

GUILFOY, WM. H. The Death-rate of New York as affected by the Cosmopolitan Character of its Population. Quar. Pub. Am. Sta. Asso., 1907.

ANDREW, J. GRANT. Age Incidence, Sex and Comparative Frequency in Disease. London, Baillière, Tindall & Cox, 1909.

CAUSES OF DEATH.

A. P. H. A. COMMITTEE REPORT. The Accuracy of Certified Causes of Death. Public Health Reports, Sept. 28, 1917, pp. 1557–1632.

U. S. BUREAU OF THE CENSUS. Manual of the International List of Causes of Death, 1911.

U. S. BUREAU OF THE CENSUS. Index of Joint Causes of Death, 1914.

U. S. BUREAU OF THE CENSUS. Physicians' Pocket Reference to the International List of Causes of Death, 1918.

PROBABILITY.

DAVENPORT, CHAS. B. Statistical Methods, with Special Reference to Biological Variations. Second edition, New York, John Wiley and Sons, Inc., 1904.

FISHER, ARNE. The Mathematical Theory of Probabilities. New York, Macmillan Co., 1915. 2d Ed., 1922.

FISHER, ARNE. An Elementary Treatise on Frequency Curves. New York, Macmillan Co., 1922.

WHIPPLE, GEORGE C. The Element of Chance in Sanitation. Jour. Franklin Institute, July and Aug., 1916.

WELD, LEROY D. Theory of Errors and Least Squares. New York, Macmillan Co., 1916.

GOODWIN, A. M. Elements of the Precision of Measurements and Graphical Methods. New York, McGraw-Hill Co., 1913.

LA PLACE, P. S., MARQUIS DE. Théorie analytique des probabilités, 1814. (Historical value.)

QUETELET, L. A. S. Lettres sur la théorie des probabilités, appliquée aux sciences morales et politiques, 1846. (English translation by O. G. Downs, 1849.)

BROWNLEE, JOHN. The Mathematical Theory of Random Migration and Epidemic Distribution. Proc. Royal Soc. of Edinburgh, Vol. 31, p. 262, 1910–11.

MERRIMAN, MANSFIELD. Least Squares. New York, John Wiley & Sons, Inc.

CORRELATION.

JEVONS, W. STANLEY. The Principles of Science. London, Macmillan Co., 1907.

PEARSON, KARL, ALICE LEE and ETHEL M. ELDERTON. On the Correlation of Death-rates. Jour. Royal Sta. Soc., Vol. 73, p. 534, 1910.

LIFE TABLES.

MOIR, HENRY. Life Assurance Primer. New York, The Spectator Co., 1912.

HENDERSON, ROBERT. Mortality Laws and Statistics. New York, John Wiley & Sons, Inc., 1915.

GLOVER, JAS. W. United States Life Tables, 1910. U. S. Census, 1916.

BURN, JOSEPH. Vital Statistics Explained. London, Constable and Company, Ltd., 1914.

ELDERTON & TIPPARD. Construction of Mortality and Sickness Tables. London, A. & C. Black (Macmillan) 1914.

APPENDIX II

THE MODEL STATE LAW FOR MORBIDITY REPORTS

ADOPTED BY THE ELEVENTH ANNUAL CONFERENCE OF STATE AND TERRITORIAL HEALTH AUTHORITIES WITH THE UNITED STATES PUBLIC HEALTH SERVICE, MINNEAPOLIS, JUNE 16, 1913.

A Bill To provide for the notification of the occurrence and prevalence of certain diseases.

Be it enacted by the Senate and General Assembly of the State of ———:

SECTION 1. It shall be, and is hereby, made the duty of the State department of health (or commissioner or board of health) to keep currently informed of the occurrence, geographic distribution, and prevalence of the preventable diseases throughout the State, and for this purpose there shall be established in the State department of health a bureau (or division) of sanitary reports which shall, under the direction of the State commissioner of health (State health officer or secretary of the State board of health), be in charge of an assistant commissioner of health who shall receive an annual salary of ——— dollars and the necessary expenses incurred in the performance of his duties. The State department of health shall provide such clerical and other assistance as may be necessary for the establishment and maintenance of said bureau.

SEC. 2. The following-named diseases and disabilities are hereby made notifiable and the occurrence of cases shall be reported as herein provided:

GROUP I. — INFECTIOUS DISEASES

Actinomycosis.
Anthrax.
Chicken-pox.
Cholera. Asiatic (also cholera nostras when Asiatic cholera is present or its importation threatened).
Continued fever lasting seven days.
Dengue.
Diphtheria.
Dysentery:
(*a*) Amebic.
(*b*) Bacillary.
Favus.
German measles.

GROUP I. — INFECTIOUS DISEASES — *Continued*

Glanders.
Hookworm disease.
Leprosy.
Malaria.
Measles.
Meningitis:
(*a*) Epidemic cerebrospinal.
(*b*) Tuberculous.
Mumps.
Ophthalmia neonatorum (conjunctivitis of new born infants).
Paragonimiasis (endemic hemoptysis).
Paratyphoid fever.
Plague.
Pneumonia.
Poliomyelitis (acute infectious).
Rabies.
Rocky Mountain spotted, or tick, fever.
Scarlet fever.
Septic sore throat.
Smallpox.
Tetanus.
Trachoma.
Trichinosis.
Tuberculosis (all forms, the organ or part affected in each case to be specified).
Typhoid fever.
Typhus fever.
Whooping cough.
Yellow fever.

GROUP II. — OCCUPATIONAL DISEASES AND INJURIES.

Arsenic poisoning.
Brass poisoning.
Carbon monoxide poisoning.
Lead poisoning.
Mercury poisoning.
Natural gas poisoning.
Phosphorous poisoning.
Wood alcohol poisoning.
Naphtha poisoning.
Bisulphide of carbon poisoning.
Dinitrobenzine poisoning.
Caisson disease (compressed-air illness).
Any other disease or disability contracted as a result of the nature of the person's employment.

GROUP III. — VENEREAL DISEASES

Gonococcus infection.
Syphilis.

GROUP IV. — DISEASES OF UNKNOWN ORIGIN.

Pellagra.
Cancer.

Provided, That the State department of health (or board of health) may from time to time, in its discretion, declare additional diseases notifiable and subject to the provisions of this act.

SEC. 3. Each and every physician practicing in the State of ——— who treats or examines any person suffering from or afflicted with, or suspected to be suffering from or afflicted with, any one of the notifiable diseases shall immediately report such case of notifiable disease in writing to the local health authority having jurisdiction. Said report shall be forwarded either by mail or by special messenger and shall give the following information:

1. The date when the report is made.

2. The name of the disease or suspected disease.

3. The name, age, sex, color, occupation, address, and school attended or place of employment of patient.

4. Number of adults and children in the household.

5. Source or probable source of infection or the origin or probable origin of the disease.

6. Name and address of the reporting physician.

Provided, That if the disease is, or is suspected to be, smallpox the report shall, in addition, show whether the disease is of the mild or virulent type and whether the patient has ever been successively vaccinated, and, if the patient has been successfully vaccinated, the number of times and dates or approximate dates of such vaccination; and if the disease is, or is suspected to be, cholera, diphtheria, plague, scarlet fever, smallpox, or yellow fever, the physician shall, in addition to the written report, give immediate notice of the case to the local health authority in the most expeditious manner available; and if the disease is, or is suspected to be, typhoid fever, scarlet fever, diphtheria or septic sore throat the report shall also show whether the patient has been, or any member of the household in which the patient resides is, engaged or employed in the handling of milk for sale or preliminary to sale: *And provided further*, That in the reports of cases of the venereal diseases the name and address of the patient need not be given.

Sec. 4. The requirements of the preceding section shall be applicable to physicians attending patients ill with any of the notifiable diseases in hospitals, asylums, or other institutions, public or private: *Provided*, That the superintendent or other person in charge of any such hospital, asylum, or other institution in which the sick are cared for may, with the written consent of the local health officer (or board of health) having jurisdiction, report in the place of the attending physician or physicians the cases of notifiable diseases and disabilities occurring in or admitted to said hospital, asylum, or other institution in the same manner as that prescribed by physicians.

Sec. 5. Whenever a person is known, or is suspected, to be afflicted with a notifiable disease, or whenever the eyes of an infant under two weeks of age become reddened, inflamed, or swollen, or contain an unnatural discharge, and no physician is in attendance, an immediate report of the existence of the case shall be made to the local health officer by the midwife, nurse, attendant, or other person in charge of the patient.

SEC. 6. Teachers or other persons employed in, or in charge of, public or private schools, including Sunday Schools, shall report immediately to the local health officer each and every known or suspected case of a notifiable disease in persons attending or employed in their respective schools.

SEC. 7. The written reports of cases of the notifiable disease required by this act of physicians shall be made upon blanks supplied for the purpose, through the local health authorities, by the State department of health. These blanks shall conform to that adopted and approved by the State and Territorial health authorities in conference with the United States Public Health Service.

SEC. 8. Local health officers or boards of health shall within seven days after the receipt by them of reports of cases of the notifiable diseases forward by mail to the State department of health the original written reports made by physicians, after first having transcribed the information given in the respective reports in a book or other form of record for the permanent files of the local health office. On each report thus forwarded the local health officer shall state whether the case to which the report pertains was visited or otherwise investigated by a representative of the local health office and whether measures were taken to prevent the spread of the disease or the occurrence of additional cases.

SEC. 9. Local health officers or boards of health shall, in addition to the provisions of section 8, report to the State department of health in such manner and at such times as the State department of health may require by regulation the number of new cases of each of the notifiable diseases reported to said local health officers or boards of health.

SEC. 10. Whenever there occurs within the jurisdiction of a local health officer or board of health an epidemic of a notifiable disease, the local health officer or board of health shall, within 30 days after the epidemic shall have subsided, make a report to the State department of health of the number of cases occurring in the epidemic, the number of cases terminating fatally, the origin of the epidemic, and the means by which the disease was spread: *Provided*, That whenever the State department of health has taken charge of the control and suppression or undertaken the investigation of the epidemic, the local health authority having jurisdiction need not make the report otherwise required.

SEC. 11. No person shall be appointed to the position of local health officer in any city, town, or county until after the qualifications of said person have been approved by the State department of health.

SEC. 12. In localities in which there are no local health officers or boards of health, and in localities in which, although there are health officers or boards of health, adequate provision has not, in the opinion of the State department of health, been made for the proper notification, investigation, and control of notifiable disease, and in localities in which the local health authorities fail to carry out the provisions of this act, the State department of health shall appoint properly qualified sanitary officers to act as local health officers and to prevent the spread of disease in and from such localities and to enforce the provisions of this act: *Provided*, That salaries and other expenses incurred under the provisions of this section shall be paid by the local authorities.

SEC. 13. Any physician or other person or persons who shall fail, neglect or refuse to comply with, or who shall violate any of the provisions of this act shall be guilty of a misdemeanor, and upon conviction thereof shall be sentenced to pay a fine of not less than ——— dollars nor more than ——— dollars or to imprisonment for not less than ——— days nor more than ——— days for each offense: *Provided*, That in the case of a physician his license to practice medicine within the State may be revoked in accordance with existing statutory provisions.

SEC. 14. No license to practice medicine shall be issued to any person until after the applicant shall have filed with the State licensing board a statement, signed and sworn to before a notary or other officer qualified to administer oaths, that said applicant has familiarized himself with the requirements of this act, a copy of which sworn statement shall be forwarded to the State department of health.

SEC. 15. Each and every person engaged in the practice of medicine shall display in a prominent place in his or her office a card upon which sections 2, 3, 4, 7, 13, 14, and 15 of this act have been printed with type not smaller than 10-point. A similar card shall be displayed in a prominent place in the office of each and every hospital, asylum, or other public or private institution for the treatment of the sick. These cards shall each be not less than 1 square foot in size and shall be furnished to institutions and licensed physicians without cost by the State department of health.

SEC. 16. The sum of ——— dollars is hereby appropriated from any money in the State treasury not otherwise appropriated for carrying out the provisions of this act.

SEC. 17. This act shall take effect immediately, and all acts or parts of acts inconsistent with the provisions of this act are hereby repealed.

THE STANDARD MORBIDITY NOTIFICATION BLANK

The following model notification blank was also adopted by the conference of state and territorial health authorities with the United States Public Health Service, June 16, 1913, as the standard notification blank referred to in section 7 of the Model Law as the one to be used in the reporting of cases of the notifiable diseases. This blank is intended to be printed on a post card

[Face of card.]

.... , 191..
(Date.)

Disease or suspected disease . ...
Patient's name .. .. , age ... ., sex .. . , color .. ..
Patient's address . . . ., occupation....... ....
School attended or place of employment . . . .
Number in household Adults . . .. , children ....
Probable source of infection or origin of disease . ...
If disease is smallpox, type . . . . , number of times successfully vaccinated and approximate dates... . . . .
If typhoid fever, scarlet fever, diphtheria, or septic sore throat, was patient, or is any member of household engaged in the production of handling of milk ....
Address of reporting physician . . . .
Signature of physician ....

[Reverse of card.]

For use of local health department.

. . . 191 , . .
(Date)

Was case investigated by health department? . . . .

Was nature of disease verified?..... . . . . .

What measures were taken to prevent the spread or the occurrence of additional cases from same origin?..... .. ..

....

Health Department,
(City)..........
(State)..........

HOSPITAL DISCHARGE CERTIFICATE

Suggested but with some additions by Bolduan for use in connection with hospital morbidity reports

DISCHARGE CERTIFICATE.

Name of hospital ... . Hospital admission No...................
Sex . Age . . . .
Weight. . . . Height ... .

How admitted — Ambulance
or
own application
or
(Tabulation No.) transfer from other hospital.

White. Hebrew.
Colored. Gentile.
Mongolian.

Place of birth ....

Patient's address ... .
Borough ....
Single or married or widowed or divorced or unknown.

Date admitted ... .
Date discharged ....
Days in hospital... . months . ...
days. . .
(If over a year, omit the days and give only years and months)

Discharged to —
Home.
Other hospital.
Convalescent retreat.
Coroner.

Occupation — (*a*) Trade, profession, or particular kind of work.

. . ..

(*b*) General nature of the industry, business, or establishment in which employed (or employer).

....

Diagnosis on admission ....
Diagnosis at discharge ....
Complications .. ..
Method of treatment .. . .
If operated upon, state nature of operation .. . .
Condition at admission . . . .
Condition on discharge. Cured. Improved. Unimproved.
Died — Autopsy.
No autopsy.

Social service work done ... .
Social service work contemplated........... ....

Signed .. ..
House Physician — Surgeon.

APPENDIX III

THE MODEL STATE LAW FOR THE REGISTRATION OF BIRTHS AND DEATHS

A BILL[1] To provide for the registration of all births and deaths in the State of———

NOTE —After the bill has been prepared for presentation to the legislature of a State, the title should be carefully revised by competent legal authority.

Be it enacted by the legislature of the State of ———

SECTION 1. That the State board of health shall have charge of the registration of births and deaths; shall prepare the necessary instructions, forms, and blanks for obtaining and preserving such records and shall procure the faithful registration of the same in each primary registration district as constituted in section 3 of this act, and in the central bureau of vital statistics at the capital of the State. The said board shall be charged with the uniform and thorough enforcement of the law throughout the State, and shall from time to time recommend any additional legislation[2] that may be necessary for this purpose.

SEC. 2. That the secretary of the State board of health shall have general supervision over the central bureau of vital statistics, which is hereby authorized to be established by said board, and which shall be under the immediate direction of the State registrar of vital statistics, whom the State board of health shall appoint within thirty days after the taking effect of this law, and who shall be a medical practitioner of not less than five years' practice in his profession, and a competent vital statistician. The State registrar of vital statistics shall hold office for four years and until his successor has been appointed and has qualified, unless such office shall sooner become vacant by death, disqualification,

[1] Before introducing this bill in any legislature it should be carefully redrafted by a competent lawyer and submitted to the Bureau of the Census for criticism.

[2] The words "and shall promulgate any additional rules or regulations" may be inserted in bills prepared for States in which the State board of health has power to make rules and regulations having the effect of law.

operation of law, or other causes. Any vacancy occurring in such office shall be filled for the unexpired term by the State board of health. At least ten days before the expiration of the term of office of the State registrar of vital statistics, his successor shall be appointed by the State board of health. The State registrar of vital statistics shall receive an annual salary at the rate of ——— dollars from the date of his entering upon the discharge of the duties of his office. The State board of health shall provide for such clerical and other assistants as may be necessary for the purposes of this act, who shall serve during the pleasure of the board, and shall fix the compensation of persons thus employed within the amount appropriated therefor by the legislature. The custodian of the capitol shall provide for the bureau of vital statistics in the State capitol at ——— suitable offices, which shall be properly equipped with fireproof vault and filing cases for the permanent and safe preservation of all official records made and returned under this act.

Sec. 3. That for the purposes of this act the State shall be divided into registration districts as follows: Each city, each incorporated town, and each township [1] shall constitute a primary registration district: *Provided*, That the State board of health may combine two or more primary registration districts when necessary to facilitate registration.

Sec. 4. That within ninety days after the taking effect of this act, or as soon thereafter as possible, the State board of health shall appoint a local registrar of vital statistics for each registration district in the State.[2] The term of office of each local registrar so appointed shall be

[1] Or other primary political unit, as "town," "precinct," "civil district," "hundred," etc. When there are no such units available, the following substitutes for section 3 may be employed: Section 3. That for the purposes of this act the State shall be divided into registration districts as follows: Each city and each incorporated town shall constitute a primary registration district; and for that portion of each county outside of the cities and incorporated towns therein the State board of health shall define and designate the boundaries of a sufficient number of rural registration districts, which districts it may change or combine from time to time as may be necessary to insure the convenience and completeness of registration.

[2] This method of appointment of local registrars by the State board of health — or perhaps by the State registrar or upon his nomination — with a reasonably long term of service and subject to removal for neglect of duty, is the preferable one for efficient service. Should there be objection, however, to the creation of new offices, the section may be redrafted so that it will provide that township, village, or city clerks, or other suitable officials, shall be the local registrars.

four years, and until his successor has been appointed and has qualified, unless such office shall sooner become vacant by death, disqualification, operation of law, or other causes: *Provided*, That in cities where health officers or other officials are, in the judgment of the State board of health, conducting effective registration of births and deaths under local ordinances at the time of the taking effect of this act such officials may be appointed as registrars in and for such cities, and shall be subject to the rules and regulations of the State registrar and to all of the provisions of this act. Any vacancy occurring in the office of local registrar of vital statistics shall be filled for the unexpired term by the State board of health. At least ten days before the expiration of the term of office of any such local registrar his successor shall be appointed by the State board of health.

Any local registrar who, in the judgment of the State board of health, fails or neglects to discharge efficiently the duties of his office as set forth in this act, or to make prompt and complete returns of births and deaths as required thereby, shall be forthwith removed by the State board of health, and such other penalties may be imposed as are provided under section 22 of this act.

Each local registrar shall, immediately upon his acceptance of appointment as such, appoint a deputy, whose duty it shall be to act in his stead in case of his absence or disability; and such deputy shall in writing accept such appointment and be subject to all rules and regulations governing local registrars. And when it appears necessary for the convenience of the people in any rural district the local registrar is hereby authorized, with the approval of the State registrar, to appoint one or more suitable persons to act as subregistrars, who shall be authorized to receive certificates and to issue burial or removal permits in and for such portions of the district as may be designated; and each subregistrar shall note on each certificate, over his signature, the date of filing, and shall forward all certificates to the local registrar of the district within ten days, and in all cases before the third day of the following month: *Provided*, That each subregistrar shall be subject to the supervision and control of the State registrar and may be by him removed for neglect or failure to perform his duty in accordance with the provisions of this act or the rules and regulations of the State registrar, and shall be subject to the same penalties for neglect of duty as the local registrar.

Sec. 5. That the body of any person whose death occurs in this State, or which shall be found dead therein, shall not be interred, deposited in a vault or tomb, cremated or otherwise disposed of, or removed from or into any registration district, or be temporarily held pending further disposition more than seventy-two hours after death, unless a permit for burial, removal, or other disposition thereof shall have been properly issued by the local registrar of the registration district in which the death occurred or the body was found.[1] And no such burial or removal permit shall be issued by any registrar until, wherever practicable, a complete and satisfactory certificate of death has been filed with him as hereinafter provided: *Provided,* That when a dead body is transported from outside the State into a registration district in ——— for burial, the transit or removal permit, issued in accordance with the law and health regulations of the place where the death occurred, shall be accepted by the local registrar of the district into which the body has been transported for burial or other disposition, as a basis upon which he may issue a local burial permit; he shall note upon the face of the burial permit the fact that it was a body shipped in for interment, and give the actual place of death; and no local registrar shall receive any fee for the issuance of burial or removal permits under this act other than the compensation provided in section 20.

Sec. 6. That a stillborn child shall be registered as a birth and also as a death, and separate certificates of both the birth and the death shall be filed with the local registrar, in the usual form and manner, the certificate of birth to contain in place of the name of the child, the word "stillbirth": *Provided,* That a certificate of birth and a certificate of death shall not be required for a child that has not advanced to the fifth month of uterogestation. The medical certificate of the cause of death shall be signed by the attending physician, if any, and shall state the cause of death as "stillborn," with the cause of the stillbirth, if known, whether a premature birth, and, if born prematurely, the period of uterogestation, in months, if known; and a burial or removal permit of the prescribed form shall be required. Midwives shall not sign certificates of death for stillborn children; but such cases, and stillbirths occurring without attendance of either physician or midwife, shall be treated as deaths without medical attendance, as provided for in section 8 of this act.

Sec. 7. That the certificate of death shall contain the following items, which are hereby declared necessary for the legal, social, and sanitary purposes subserved by registration records:[2]

[1] A special proviso may be required for sparsely settled portions of a State.

[2] The following items are those of the United States standard certificate of death, approved by the Bureau of the Census.

(1) Place of death, including State, county, township, village, or city. If in a city, the ward, street, and house number; if in a hospital or other institution, the name of the same to be given instead of the street and house number. If in an industrial camp, the name of the camp to be given.

(2) Full name of decedent. If an unnamed child, the surname preceded by "Unnamed."

(3) Sex.

(4) Color or race, as white, black, mulatto (or other negro descent), Indian, Chinese, Japanese, or other.

(5) Conjugal condition, as single, married, widowed, or divorced.

(6) Date of birth, including the year, month, and day.

(7) Age, in years, months, and days. If less than one day, the hours or minutes.

(8) Occupation. The occupation to be reported of any person, male or female, who had any remunerative employment, with the statement of (*a*) trade, profession or particular kind of work; (*b*) general nature of industry, business, or establishment in which employed (or employer).

(9) Birthplace; at least State or foreign country, if known.

(10) Name of father.

(11) Birthplace of father; at least State or foreign country, if known.

(12) Maiden name of mother.

(13) Birthplace of mother; at least State or foreign country, if known.

(14) Signature and address of informant.

(15) Official signature of registrar, with the date when certificate was filed, and registered number.

(16) Date of death, year, month, and day.

(17) Certification as to medical attendance on decedent, fact and time of death, time last seen alive, and the cause of death, with contributory (secondary) cause of complication, if any, and duration of each, and whether attributed to dangerous or insanitary conditions of employment; signature and address of physician or official making the medical certificate.

(18) Length of residence (for inmates of hospitals and other institutions; transients or recent residents) at place of death and in the State, together with the place where disease was contracted, if not at place of death, and former or usual residence.

(19) Place of burial or removal; date of burial.

(20) Signature and address of undertaker or person acting as such.

The personal and statistical particulars (items 1 to 13) shall be authenticated by the signature of the informant, who may be any competent person acquainted with the facts.

The statement of facts relating to the disposition of the body shall be signed by the undertaker or person acting as such.

The medical certificate shall be made and signed by the physician, if any, last in attendance on the deceased, who shall specify the time in attendance, the time he last saw the deceased alive, and the hour of the day at which death occurred. And he shall further state the cause of death, so as to show the course of disease or sequence of causes resulting in the death, giving first the name of the disease causing death (primary cause), and the contributory (secondary) cause, if any, and the duration of each. Indefinite and unsatisfactory terms, denoting only symptoms of disease or conditions resulting from disease, will not be held sufficient for the issuance of a burial or removal permit; and any certificate containing only such terms as defined by the State Registrar shall be returned to the physician or person making the medical certificate for correction and more definite statement. Causes of death which may be the result of either disease or violence shall be carefully defined; and if from violence, the means of injury shall be stated and whether (probably) accidental, suicidal, or homicidal.[1] And for deaths in hospitals, institutions, or of nonresidents the physician shall supply the information required under this head (item 18), if he is able to do so, and may state where, in his opinion, the disease was contracted.

SEC. 8. That in case of any death occurring without medical attendance it shall be the duty of the undertaker to notify the local registrar of such death, and when so notified the registrar shall, prior to the issuance of the permit, inform the local health officer and refer the case to him for immediate investigation and certification: *Provided*, That when the local health officer is not a physician, or when there is no such official, and in such cases only, the registrar is authorized to make the certificate and return from the statement of relatives or other persons having adequate knowledge of the facts: *Provided further*, That if the registrar has reason to believe that the death may have been due to unlawful act or neglect he shall then refer the case to the coroner or other proper officer for his investigation and certification. And the coroner or other proper officer whose duty it is to hold an inquest on the

[1] In some States the question whether a death was accidental, suicidal, or homicidal must be determined by the coroner or medical examiner and the registration law must be framed to harmonize.

body of any deceased person and to make the certificate of death required for a burial permit shall state in his certificate the name of the disease causing death, or if from external causes, (1) the means of death and (2) whether (probably) accidental, suicidal, or homicidal, and shall in any case furnish such information as may be required by the State Registrar in order properly to classify the death.

SEC. 9. That the undertaker or person acting as undertaker shall file the certificate of death with the local registrar of the district in which the death occurred and obtain a burial or removal permit prior to any disposition of the body. He shall obtain the required personal and statistical particulars from the person best qualified to supply them, over the signature and address of his informant. He shall then present the certificate to the attending physician, if any, or to the health officer or coroner, as directed by the local registrar, for the medical certificate of the cause of death and other particulars necessary to complete the record, as specified in sections 7 and 8. And he shall then state the facts required relative to the date and place of burial or removal, over his signature and with his address, and present the completed certificate to the local registrar in order to obtain a permit for burial, removal, or other disposition of the body. The undertaker shall deliver the burial permit to the person in charge of the place of burial before interring or otherwise disposing of the body, or shall attach the removal permit to the box containing the corpse, when shipped by any transportation company, said permit to accompany the corpse to its destination, where, if within the State of ———, it shall be delivered to the person in charge of the place of burial

[Every person, firm, or corporation selling a casket shall keep a record showing the name of the purchaser, purchaser's post-office address, name of deceased, date of death, and place of death of deceased, which record shall be open to inspection of the State Registrar at all times. On the first day of each month the person, firm, or corporation selling caskets shall report to the State Registrar each sale for the preceding month, on a blank, provided for that purpose: *Provided, however*, That no person, firm, or corporation selling caskets to dealers or undertakers only shall be required to keep such record, nor shall such report be required from undertakers when they have direct charge of the disposition of a dead body.

Every person, firm, or corporation selling a casket at retail, and not having charge of the disposition of the body, shall inclose within the casket a notice furnished by the State Registrar calling attention to the requirements of the law, a blank certificate of death, and the rules and regulations of the State board of health concerning the burial or other disposition of a dead body.][1]

Sec. 10. That if the interment or other disposition of the body is to be made within the State, the wording of the burial or removal permit may be limited to a statement by the registrar, and over his signature, that a satisfactory certificate of death having been filed with him, as required by law, permission is granted to inter, remove, or dispose otherwise of the body, stating the name, age, sex, cause of death, and other necessary details upon the form prescribed by the State registrar.

Sec. 11. That no person in charge of any premises on which interments are made shall inter or permit the interment or other disposition of any body unless it is accompanied by a burial, removal, or transit permit, as herein provided. And such person shall indorse upon the permit the date of interment, over his signature, and shall return all permits so indorsed to the local registrar of his district within ten days from the date of interment, or within the time fixed by the local board of health. He shall keep a record of all bodies interred or otherwise disposed of on the premises under his charge, in each case stating the name of each deceased person, place of death, date of burial or disposal, and name and address of the undertaker; which record shall at all times be open to official inspection: *Provided,* That the undertaker, or person acting as such, when burying a body in a cemetery or burial ground having no person in charge, shall sign the burial or removal permit, giving the date of burial, and shall write across the face of the permit the words "No person in charge," and file the burial or removal permit within ten days with the registrar of the district in which the cemetery is located.

Sec. 12. That the birth of each and every child born in this State shall be registered as hereinafter provided.

Sec. 13. That within ten days after the date of each birth there shall be filed with the local registrar of the district in which the birth occurred a certificate of such birth, which certificate shall be upon the form adopted by the State board of health with a view to procuring a full and accurate report with respect to each item of information enumerated in section 14 of this act.[2]

In each case where a physician, midwife, or person acting as midwife was in attendance upon the birth, it shall be the duty of such physician,

[1] The provisions in brackets may be useful in States in which many funerals are conducted without regular undertakers.

[2] A proviso may be added that shall require the registration, or notification, at a shorter interval than ten days, of births that occur in cities.

midwife, or person acting as midwife to file in accordance herewith the certificate herein contemplated.

In each case where there was no physician, midwife, or person acting as midwife in attendance upon the birth, it shall be the duty of the father or mother of the child, the householder or owner of the premises where the birth occurred, or the manager or superintendent of the public or private institution where the birth occurred, each in the order named, within ten days after the date of such birth, to report to the local registrar the fact of such birth. In such case and in case the physician, midwife, or person acting as midwife, in attendance upon the birth is unable, by diligent inquiry, to obtain any item or items of information contemplated in section 14 of this act, it shall then be the duty of the local registrar to secure from the person so reporting, or from any other person having the required knowledge, such information as will enable him to prepare the certificate of birth herein contemplated, and it shall be the duty of the person reporting the birth, or who may be interrogated in relation thereto, to answer correctly and to the best of his knowledge all questions put to him by the local registrar which may be calculated to elicit any information needed to make a complete record of the birth as contemplated by said section 14, and it shall be the duty of the informant as to any statement made in accordance herewith to verify such statement by his signature, when requested so to do by the local registrar.

Sec. 14. That the certificate of birth shall contain the following items, which are hereby declared necessary for the legal, social, and sanitary purposes subserved by registration records:[1]

(1) Place of birth, including State, county, township or town, village, or city. If in a city, the ward, street, and house number; if in a hospital or other institution, the name of the same to be given, instead of the street and house number.

(2) Full name of child. If the child dies without a name, before the certificate is filed, enter the words "Died unnamed." If the living child has not yet been named at the date of filing certificate of birth, the space for "Full name of child" is to be left blank, to be filled out subsequently by a supplemental report, as hereinafter provided.

(3) Sex of child.

(4) Whether a twin, triplet, or other plural birth. A separate certificate shall be required for each child in case of plural births.

[1] The following items are those of the United States standard certificate of birth, approved by the Bureau of the Census.

(5) For plural births, number of each child in order of birth.
(6) Whether legitimate or illegitimate.[1]
(7) Date of birth, including the year, month, and day.
(8) Full name of father.
(9) Residence of father.
(10) Color or race of father.
(11) Age of father at last birthday, in years.
(12) Birthplace of father; at least State or foreign country, if known.
(13) Occupation of father. The occupation to be reported if engaged in any remunerative employment, with the statement of (*a*) trade, profession, or particular kind of work; (*b*) general nature of industry, business, or establishment in which employed (or employer).
(14) Maiden name of mother.
(15) Residence of mother.
(16) Color or race of mother.
(17) Age of mother at last birthday, in years.
(18) Birthplace of mother; at least State or foreign country, if known.
(19) Occupation of mother. The occupation to be reported if engaged in any remunerative employment, with the statement of (*a*) trade, profession, or particular kind of work; (*b*) general nature of industry, business, or establishment in which employed (or employer).
(20) Number of children born to this mother, including present birth.
(21) Number of children of this mother living.
(22) The certification of attending physician or midwife as to attendance at birth, including statement of year, month, day (as given in item 7), and hour of birth, and whether the child was born alive or stillborn. This certification shall be signed by the attending physician or midwife, with date of signature and address; if there is not physician or midwife in attendance, then by the father or mother of the child, householder, owner of the premises, or manager or superintendent of public or private institution where the birth occurred, or other competent person, whose duty it shall be to notify the local registrar of such birth, as required by section 13 of this act.
(23) Exact date of filing in office of local registrar, attested by his official signature, and registered number of birth, as hereinafter provided.

SEC. 15. That when any certificate of birth of a living child is presented without the statement of the given name, then the local registrar

[1] This question may be omitted if desired, or provision may be made so that the identity of parents will not be disclosed.

shall make out and deliver to the parents of the child a special blank for the supplemental report of the given name of the child, which shall be filled out as directed, and returned to the local registrar as soon as the child shall have been named.

SEC. 16. That every physician, midwife, and undertaker shall, without delay, register his or her name, address, and occupation with the local registrar of the district in which he or she resides, or may hereafter establish a residence; and shall thereupon be supplied by the local registrar with a copy of this act, together with such rules and regulations as may be prepared by the State registrar relative to its enforcement. Within thirty days after the close of each calendar year each local registrar shall make a return to the State registrar of all physicians, midwives, or undertakers who have been registered in his district during the whole or any part of the preceding calendar year: *Provided*, That no fee or other compensation shall be charged by local registrars to physicians, midwives, or undertakers for registering their names under this section or making returns thereof to the State registrar.[1]

SEC. 17. That all superintendents or managers, or other persons in charge of hospitals, almshouses, lying-in, or other institutions, public or private, to which persons resort for treatment of diseases, confinement, or are committed by process of law, shall make a record of all the personal and statistical particulars relative to the inmates in their institutions at the date of approval of this act, which are required in the forms of the certificates provided for by this act, as directed by the State registrar; and thereafter such record shall be, by them, made for all future inmates at the time of their admittance. And in case of persons admitted or committed for treatment of disease, the physician in charge shall specify for entry in the record, the nature of the disease, and where, in his opinion, it was contracted. The personal particulars and information required by this section shall be obtained from the individual himself if it is practicable to do so; and when they can not be so obtained, they shall be obtained in as complete a manner as possible from relatives, friends, or other persons acquainted with the facts.

SEC. 18. That the State registrar shall prepare, print, and supply to all registrars all blanks and forms used in registering, recording, and preserving the returns, or in otherwise carrying out the purposes of this act; and shall prepare and issue such detailed instructions as may be required to procure the uniform observance of its provisions and the

[1] This section may be omitted if deemed expedient and the duty of supplying instructions may be assumed by the State officer.

maintenance of a perfect system of registration; and no other blanks shall be used than those supplied by the State registrar He shall carefully examine the certificates received monthly from the local registrars, and if any such are incomplete or unsatisfactory he shall require such further information to be supplied as may be necessary to make the record complete and satisfactory. And all physicians, midwives, informants, or undertakers, and all other persons having knowledge of the facts, are hereby required to supply, upon a form provided by the State registrar or upon the original certificate, such information as they may possess regarding any birth or death upon demand of the State registrar, in person, by mail, or through the local registrar: *Provided*, That no certificate of birth or death, after its acceptance for registration by the local registrar, and no other record made in pursuance of this act, shall be altered or changed in any respect otherwise than by amendments properly dated, signed, and witnessed The State registrar shall further arrange, bind, and permanently preserve the certificates in a systematic manner, and shall prepare and maintain a comprehensive and continuous card index of all births and deaths registered; said index to be arranged alphabetically, in the case of deaths, by the names of decendents, and in the case of births, by the names of fathers and mothers. He shall inform all registrars what diseases are to be considered infectious, contagious, or communicable and dangerous to the public health, as decided by the State board of health, in order that when deaths occur from such diseases proper precautions may be taken to prevent their spread.

If any cemetery company or association, or any church or historical society or association, or any other company, society, or association, or any individual, is in possession of any record of births or deaths which may be of value in establishing the genealogy of any resident of this State, such company, society, association, or individual may file such record or a duly authenticated transcript thereof with the State registrar, and it shall be the duty of the State registrar to preserve such record or transcript and to make a record and index thereof in such form as to facilitate the finding of any information contained therein. Such record and index shall be open to inspection by the public, subject to such reasonable conditions as the State registrar may prescribe. If any person desires a transcript of any record filed in accordance herewith, the State registrar shall furnish the same upon application, together with a certificate that it is a true copy of such record, as filed in his office, and for his services in so furnishing such transcript and certificate he shall be entitled to a fee of (ten cents per folio) (fifty cents per hour or fraction of an hour necessarily consumed in making such transcript) and to a fee of twenty-five cents for the certificate, which fees shall be paid by the applicant.

SEC. 19. That each local registrar shall supply blank forms of certificates to such persons as require them. Each local registrar shall carefully examine each certificate of birth or death when presented for record in order to ascertain whether or not it has been made out in accordance with the provisions of this act and the instructions of the State registrar; and if any certificate of death is incomplete or unsatisfactory, it shall be his duty to call attention to the defects in the return, and to withhold the burial or removal permit until such defects are corrected. All certificates, either of birth or of death, shall be written legibly, in durable black ink, and no certificate shall be held to be complete and correct that does not supply all of the items of information called for therein, or satisfactorily account for their omission. If the certificate of death is properly executed and complete, he shall then issue a burial or removal permit to the undertaker; provided, that in case the death occurred from some disease which is held by the State board of health to be infectious, contagious, or communicable and dangerous to the public health, no permit for the removal or other disposition of the body shall be issued by the registrar, except under such conditions as may be prescribed by the State board of health. If a certificate of birth is incomplete, the local registrar shall immediately notify the informant and require him to supply the missing items of information if they can be obtained. He shall number consecutively the certificates of birth and death, in two separate series, beginning with number 1 for the first birth and the first death in each calendar year, and sign his name as registrar in attest of the date of filing in his office. He shall also make a complete and accurate copy of each birth and each death certificate registered by him in a record book supplied by the State registrar, to be preserved permanently in his office as the local record, in such manner as directed by the State registrar. And he shall, on the tenth day of each month, transmit to the State registrar all original certificates registered by him for the preceding month. And if no births or no deaths occurred in any month, he shall, on the tenth day of the following month, report that fact to the State registrar, on a card provided for such purpose.

SEC. 20. That each local registrar shall be paid the sum of twenty-five cents for each birth certificate and each death certificate properly and completely made out and registered with him, and correctly recorded and promptly returned by him to the State registrar, as required by this act.[1] And in case no births or no deaths were registered during any month, the local registrar shall be entitled to be paid the sum of twenty-five cents for each report to that effect, but only if such report be made promptly as required by this act. All amounts payable to a local registrar under the provisions of this section shall be paid by the treasurer of the county in which the registration district is located, upon certification by the State registrar. And the State registrar shall annually certify to the treasurers of the several counties the number of births and deaths properly registered, with the names of the local registrars and the amounts due each at the rates fixed herein.[2]

SEC. 21. That the State registrar shall, upon request, supply to any applicant a certified copy of the record of any birth or death registered under provisions of this act, for the making and certification of which he shall be entitled to a fee of fifty cents, to be paid by the applicant. And any such copy of the record of a birth or death, when properly certified by the State registrar, shall be prima facie evidence in all courts and places of the facts therein stated. For any search of the files and records when no certified copy is made, the State registrar shall be entitled to a fee of fifty cents for each hour or fractional part of an hour of time of search, said fee to be paid by the applicant. And the State registrar shall keep a true and correct account of all fees by him received under these provisions, and turn the same over to the State treasurer: *Provided,* That the State registrar shall, upon request of any parent or guardian, supply, without fee, a certificate limited to a statement as to the date of birth of any child when the same shall be necessary for admission to school, or for the purpose of securing employment: *And provided further,* That the United States Census Bureau may obtain, without expense to the State, transcripts, or certified copies of births and deaths without payment of the fees herein prescribed.

SEC. 22. That any person, who for himself or as an officer, agent, or employee of any other person, or of any corporation or partnership (*a*) shall inter, cremate, or otherwise finally dispose of the dead body of a human being, or permit the same to be done, or shall remove said body from the primary registration district in which the death occurred or

[1] A proviso may be inserted at this point relative to fees of city registrars who are already compensated by salary for their services. See laws of Missouri, Ohio, and Pennsylvania.

[2] Provision may be made in this section for the payment of subregistrars and also, if desired, for the payment of physicians and midwives. See Kentucky law.

the body was found without the authority of a burial or removal permit issued by the local registrar of the district in which the death occurred or in which the body was found; or (*b*) shall refuse or fail to furnish correctly any information in his possession, or shall furnish false information affecting any certificate or record, required by this act; or (*c*) shall willfully alter, otherwise than is provided by section 18 of this act, or shall falsify any certificate of birth or death, or any record established by this act; or (*d*) being required by this act to fill out a certificate of birth or death and file the same with the local registrar, or deliver it, upon request, to any person charged with the duty of filling the same, shall fail, neglect, or refuse to perform such duty in the manner required by this act; or (*e*) being a local registrar, deputy registrar, or subregistrar, shall fail, neglect, or refuse to perform his duty as required by this act and by the instructions and direction of the State registrar thereunder, shall be deemed guilty of a misdemeanor, and upon conviction thereof shall for the first offense be fined not less than five dollars ($5) nor more than fifty dollars ($50), and for each subsequent offense not less than ten dollars ($10) nor more than one hundred dollard ($100), or be imprisoned in the county jail not more than sixty days, or be both fined and imprisoned in the discretion of the court.[1]

Sec. 23. That each local registrar is hereby charged with the strict and thorough enforcement of the provisions of this act in his registration district, under the supervision and direction of the State registrar. And he shall make an immediate report to the State registrar of any violation of this law coming to his knowledge, by observation or upon complaint of any person or otherwise.

The State registrar is hereby charged with the thorough and efficient execution of the provisions of this act in every part of the State, and is hereby granted supervisory power over local registrars, deputy local registrars, and subregistrars to the end that all of its requirements shall be uniformly complied with. The State registrar, either personally or by an accredited representative, shall have authority to investigate cases of irregularity or violation of law, and all registrars shall aid him upon request, in such investigations. When he shall deem it necessary he shall report cases of violation of any of the provisions of this act to the prosecuting attorney of the county, with a statement of the facts

[1] Provision may be made whereby compliance with this act shall constitute a condition of granting licenses to physicians, midwives, and embalmers.

and circumstances; and when any such case is reported to him by the State registrar the prosecuting attorney shall forthwith initiate and promptly follow up the necessary court proceedings against the person or corporation responsible for the alleged violation of law. And upon request of the State registrar, the attorney general shall assist in the enforcement of the provisions of this act.

NOTE. — Other sections should be added giving the date on which the act is to go into effect, if not determined by constitutional provisions of the State; providing for the financial support of the law; and repealing prior statutes inconsistent with the present act.

It is desirable that the entire bill should be reviewed by competent legal authority for the purpose of discovering whether it can be made more consistent in any respect with the general form of legislation of the State in which the bill is to be introduced, without material change or injury to the effectiveness of registration.

THE STANDARD BIRTH AND DEATH CERTIFICATES

The following are facsimile reproductions of the standard birth and death certificates. They have been reduced in size to meet the requirements of the printed page. The size of the birth certificate is $6\frac{1}{8}$ by $7\frac{7}{8}$ inches, and of the death certificate $7\frac{1}{4}$ by $8\frac{1}{2}$ inches. Copies can be obtained from the Director of the Census upon request.

8-334e
V.S. No. 110

(Instructions on certain points may be printed on the back
Size of certificate, $6\frac{1}{8} \times 7\frac{7}{8}$ in.)

MARGIN RESERVED FOR BINDING

WRITE PLAINLY, WITH UNFADING INK — THIS IS A PERMANENT RECORD

N. B. — In case of more than one child at a birth, a SEPARATE RETURN must be made for each, and the number of each, in order of birth, stated.

DEPARTMENT OF COMMERCE — BUREAU OF THE CENSUS

STANDARD CERTIFICATE OF BIRTH

State File No..............

Registered No.............

1. PLACE OF BIRTH —
   - COUNTY .... STATE ....
   - TOWNSHIP .... OR VILLAGE ....
   - CITY .... No. .... ST. .... WARD

(If birth occurred in a hospital or institution, give its NAME instead of street and number)

2 Full name of child — { If child is not yet named, make supplemental report, as directed

3 Sex of child	*To be answered ONLY in event of plural births* { 4. Twin, triplet or other / 5 Number, in order of birth	6. Legitimate?	7. Date of birth . (Month, day, year)

FATHER	MOTHER
8 Full name	14. Full maiden name
9. Residence (Usual place of abode) If nonresident, give place and State	15. Residence (Usual place of abode) If nonresident, give place and State
10. Color or race | 11 Age at last birthday (Years)	16. Color or race | 17 Age at last birthday ..... (Years)
12. Birthplace (city or place) (State or country)	18. Birthplace (city or place) (State or country) ....
13. Occupation Nature of industry	19. Occupation Nature of industry

20. Number of children of this mother (Taken as of time of birth of child herein certified and including this child.) } (a) Born alive and now living (b) Born alive but now dead ... (c) Stillborn......

CERTIFICATE OF ATTENDING PHYSICIAN OR MIDWIFE*

I hereby certify that I attended the birth of this child, who was . . at . . m. on the date above stated ....
(Born alive *or* stillborn)

{ ** When there was no attending physician or midwife, then the father, householder, etc., should make this return. A stillborn child is one that neither breathes nor shows other evidence of life after birth* }

Signature ....
....
(Physician or Midwife)

Given name added from a supplemental report ....
(Month, day, year)

Address..

....
Registrar.

Filed............., 19.... ....
Registrar.

MARGIN RESERVED FOR BINDING

This supplemental report is to be pasted beneath the original

8–442

V. S No. 108

SUPPLEMENTAL REPORT OF BIRTH

(STATE)

(This return should preferably be made by the person who made the original)

Registered Number[1] . ..

Place of birth[1] . . *No.*.... ... . *St.*

(Registration district)

SEX of CHILD [1]	Twin,[1] triplet, or other? and	Number [1] in order of birth

DATE OF BIRTH [1] 190
(Month) (Day) (Year)

FULL [1] NAME	FATHER
FULL [1] MAIDEN NAME	MOTHER

[1] These items to be entered by the Registrar before giving out this form.

I HEREBY CERTIFY that the child described herein has been named:

. . . .
(Give name in full) (Surname)

(Signature) ... .

... .
(Physician or midwife)

11–3

8-209d
V.S. No. 98
N.B.—WRITE PLAINLY, WITH UNFADING INK—THIS IS A PERMANENT RECORD. Every item of information should be carefully supplied. AGE should be stated EXACTLY. PHYSICIANS should state CAUSE OF DEATH in plain terms, so that it may be properly classified. Exact statement of OCCUPATION is very important. See instructions on back of certificate.

MARGIN RESERVED FOR BINDING

DEPARTMENT OF COMMERCE
BUREAU OF THE CENSUS

STANDARD CERTIFICATE OF DEATH

1 PLACE OF DEATH
County .. . State . Registered No. .
Township or Village . . or
City . .No. , St , . Ward
(If death occurred in a hospital or institution, give its NAME instead of street and number.)

2 FULL NAME . .
(a) Residence No. St , Ward . . . .
(Usual place of abode) (If nonresident give city or town and State)
Length of residence in city or town where death occurred. yrs. mos ds. How long in U. S, if of foreign birth? yrs. mos. ds.

PERSONAL AND STATISTICAL PARTICULARS				MEDICAL CERTIFICATE OF DEATH
3 SEX	4 COLOR OR RACE	5 Single, Married, Widowed, or Divorced (Write the word)		16 DATE OF DEATH (month, day, and year) 19

5a If married, widowed, or divorced HUSBAND of (or) WIFE of

6 DATE OF BIRTH (month, day, and year)

7 AGE Yrs	Mos	Ds	If LESS than 1 day, hrs or min ?

8 OCCUPATION OF DECEASED
(a) Trade, profession, or particular kind of work
(b) General nature of industry, business, or establishment in which employed (or employer)
(c) Name of employer .

9 BIRTHPLACE (city or town).. .
(State or country)

PARENTS
10 NAME OF FATHER
11 BIRTHPLACE OF FATHER (city or town)
(State or country) .
12 MAIDEN NAME OF MOTHER
13 BIRTHPLACE OF MOTHER (city or town) .
(State or country)

14 Informant..... .. ..
(Address)

15 Filed . . . , 19 .. ..
Registrar

17 I HEREBY CERTIFY, That I attended deceased from
, 19 .., to . .. , 19..
that I last saw h alive on . , 19 .
and that death occurred, on the date stated above, at . ..m.
The CAUSE OF DEATH* was as follows:
... .
. . . .
. . . .
. (duration) yrs. . mos...ds.
CONTRIBUTORY..... .. . .
(Secondary)
. (duration). .yrs. .mos...ds.
18 Where was disease contracted if not at place of death? .. . ..
Did an operation precede death? . . Date of ....
Was there an autopsy? ....
What test confirmed diagnosis?....
(Signed) . . . . , M.D.
, 19 (Address)

*State the Disease Causing Death, or in deaths from Violent Causes, state (1) Means and Nature of Injury, and (2) whether Accidental, Suicidal, or Homicidal. (See reverse side for additional space)

19 PLACE OF BURIAL, CREMATION, OR REMOVAL	DATE OF BURIAL 19
20 UNDERTAKER	ADDRESS

APPENDIX IV

TABLE VI.—LOGARITHMS OF NUMBERS.

N	0	1	2	3	4	5	6	7	8	9
100	00000	00043	00087	00130	00173	00217	00260	00303	00346	00389
1	0432	0475	0518	0561	0604	0647	0689	0732	0775	0817
2	0860	0903	0945	0988	1030	1072	1115	1157	1199	1242
3	1284	1326	1368	1410	1452	1494	1536	1578	1620	1662
4	1703	1745	1787	1828	1870	1912	1953	1995	2036	2078
5	2119	2160	2202	2243	2284	2325	2366	2407	2449	2490
6	2531	2572	2612	2653	2694	2735	2776	2816	2857	2898
7	2938	2979	3019	3060	3100	3141	3181	3222	3262	3302
8	3342	3383	3423	3463	3503	3543	3583	3623	3663	3703
9	3743	3782	3822	3862	3902	3941	3981	4021	4060	4100
110	04139	04179	04218	04258	04297	04336	04376	04415	04454	04493
1	4532	4571	4610	4650	4689	4727	4766	4805	4844	4883
2	4922	4961	4999	5038	5077	5115	5154	5192	5231	5269
3	5308	5346	5385	5423	5461	5500	5538	5576	5614	5652
4	5690	5729	5767	5805	5843	5881	5918	5956	5994	6032
5	6070	6108	6145	6183	6221	6258	6296	6333	6371	6408
6	6446	6483	6521	6558	6595	6633	6670	6707	6744	6781
7	6819	6856	6893	6930	6967	7004	7041	7078	7115	7151
8	7188	7225	7262	7298	7335	7372	7408	7445	7482	7518
9	7555	7591	7628	7664	7700	7737	7773	7809	7846	7882
120	07918	07954	07990	08027	08063	08099	08135	08171	08207	08243
1	8279	8314	8350	8386	8422	8458	8493	8529	8565	8600
2	8636	8672	8707	8743	8778	8814	8849	8884	8920	8955
3	8991	9026	9061	9096	9132	9167	9202	9237	9272	9307
4	9342	9377	9412	9447	9482	9517	9552	9587	9621	9656
5	9691	9726	9760	9795	9830	9864	9899	9934	9968	10003
6	10037	10072	10106	10140	10175	10209	10243	10278	10312	0346
7	0380	0415	0449	0483	0517	0551	0585	0619	0653	0687
8	0721	0755	0789	0823	0857	0890	0924	0958	0992	1025
9	1059	1093	1126	1160	1193	1227	1261	1294	1327	1361
130	11394	11428	11461	11494	11528	11561	11594	11628	11661	11694
1	1727	1760	1793	1826	1860	1893	1926	1959	1992	2024
2	2057	2090	2123	2156	2189	2222	2254	2287	2320	2352
3	2385	2418	2450	2483	2516	2548	2581	2613	2646	2678
4	2710	2743	2775	2808	2840	2872	2905	2937	2969	3001
5	3033	3066	3098	3130	3162	3194	3226	3258	3290	3322
6	3354	3386	3418	3450	3481	3513	3545	3577	3609	3640
7	3672	3704	3735	3767	3799	3830	3862	3893	3925	3956
8	3988	4019	4051	4082	4114	4145	4176	4208	4239	4270
9	4301	4333	4364	4395	4426	4457	4489	4520	4551	4582
140	14613	14644	14675	14706	14737	14768	14799	14829	14860	14891
1	4922	4953	4983	5014	5045	5076	5106	5137	5168	5198
2	5229	5259	5290	5320	5351	5381	5412	5442	5473	5503
3	5534	5564	5594	5625	5655	5685	5715	5746	5776	5806
4	5836	5866	5897	5927	5957	5987	6017	6047	6077	6107
5	6137	6167	6197	6227	6256	6286	6316	6346	6376	6406
6	6435	6465	6495	6524	6554	6584	6613	6643	6673	6702
7	6732	6761	6791	6820	6850	6879	6909	6938	6967	6997
8	7026	7056	7085	7114	7143	7173	7202	7231	7260	7289
9	7319	7348	7377	7406	7435	7464	7493	7522	7551	7580
150	17609	17638	17667	17696	17725	17754	17782	17811	17840	17869

N	0	1	2	3	4	5	6	7	8	9
150	17609	17638	17667	17696	17725	17754	17782	17811	17840	17869
1	7898	7926	7955	7984	8013	8041	8070	8099	8127	8156
2	8184	8213	8241	8270	8298	8327	8355	8384	8412	8441
3	8469	8498	8526	8554	8583	8611	8639	8667	8696	8724
4	8752	8780	8808	8837	8865	8893	8921	8949	8977	9005
5	9033	9061	9089	9117	9145	9173	9201	9229	9257	9285
6	9312	9340	9368	9396	9424	9451	9479	9507	9535	9562
7	9590	9618	9645	9673	9700	9728	9756	9783	9811	9838
8	9866	9893	9921	9948	9976	20003	20030	20058	20085	20112
9	20140	20167	20194	20222	20249	0276	0303	0330	0358	0385
160	20412	20439	20466	20493	20520	20548	20575	20602	20629	20656
1	0683	0710	0737	0763	0790	0817	0844	0871	0898	0925
2	0952	0978	1005	1032	1059	1085	1112	1139	1165	1192
3	1219	1245	1272	1299	1325	1352	1378	1405	1431	1458
4	1484	1511	1537	1564	1590	1617	1643	1669	1696	1722
5	1748	1775	1801	1827	1854	1880	1906	1932	1958	1985
6	2011	2037	2063	2089	2115	2141	2167	2194	2220	2246
7	2272	2298	2324	2350	2376	2401	2427	2453	2479	2505
8	2531	2557	2583	2608	2634	2660	2686	2712	2737	2763
9	2789	2814	2840	2866	2891	2917	2943	2968	2994	3019
170	23045	23070	23096	23121	23147	23172	23198	23223	23249	23274
1	3300	3325	3350	3376	3401	3426	3452	3477	3502	3528
2	3553	3578	3603	3629	3654	3679	3704	3729	3754	3779
3	3805	3830	3855	3880	3905	3930	3955	3980	4005	4030
4	4055	4080	4105	4130	4155	4180	4204	4229	4254	4279
5	4304	4329	4353	4378	4403	4428	4452	4477	4502	4527
6	4551	4576	4601	4625	4650	4674	4699	4724	4748	4773
7	4797	4822	4846	4871	4895	4920	4944	4969	4993	5018
8	5042	5066	5091	5115	5139	5164	5188	5212	5237	5261
9	5285	5310	5334	5358	5382	5406	5431	5455	5479	5503
180	25527	25551	25575	25600	25624	25648	25672	25696	25720	25744
1	5768	5792	5816	5840	5864	5888	5912	5935	5959	5983
2	6007	6031	6055	6079	6102	6126	6150	6174	6198	6221
3	6245	6269	6293	6316	6340	6364	6387	6411	6435	6458
4	6482	6505	6529	6553	6576	6600	6623	6647	6670	6694
5	6717	6741	6764	6788	6811	6834	6858	6881	6905	6928
6	6951	6975	6998	7021	7045	7068	7091	7114	7138	7161
7	7184	7207	7231	7254	7277	7300	7323	7346	7370	7393
8	7416	7439	7462	7485	7508	7531	7554	7577	7600	7623
9	7646	7669	7692	7715	7738	7761	7784	7807	7830	7852
190	27875	27898	27921	27944	27967	27989	28012	28035	28058	28081
1	8103	8126	8149	8171	8194	8217	8240	8262	8285	8307
2	8330	8353	8375	8398	8421	8443	8466	8488	8511	8533
3	8556	8578	8601	8623	8646	8668	8691	8713	8735	8758
4	8780	8803	8825	8847	8870	8892	8914	8937	8959	8981
5	9003	9026	9048	9070	9092	9115	9137	9159	9181	9203
6	9226	9248	9270	9292	9314	9336	9358	9380	9403	9425
7	9447	9469	9491	9513	9535	9557	9579	9601	9623	9645
8	9667	9688	9710	9732	9754	9776	9798	9820	9842	9863
9	9885	9907	9929	9951	9973	9994	30016	30038	30060	30081
200	30103	30125	30146	30168	30190	30211	30233	30255	30276	30298

N	0	1	2	3	4	5	6	7	8	9
200	30103	30125	30146	30168	30190	30211	30233	30255	30276	30298
1	0320	0341	0363	0384	0406	0428	0449	0471	0492	0514
2	0535	0557	0578	0600	0621	0643	0664	0685	0707	0728
3	0750	0771	0792	0814	0835	0856	0878	0899	0920	0942
4	0963	0984	1006	1027	1048	1069	1091	1112	1133	1154
5	1175	1197	1218	1239	1260	1281	1302	1323	1345	1366
6	1387	1408	1429	1450	1471	1492	1513	1534	1555	1576
7	1597	1618	1639	1660	1681	1702	1723	1744	1765	1785
8	1806	1827	1848	1869	1890	1911	1931	1952	1973	1994
9	2015	2035	2056	2077	2098	2118	2139	2160	2181	2201
210	32222	32243	32263	32284	32305	32325	32346	32366	32387	32408
1	2428	2449	2469	2490	2510	2531	2552	2572	2593	2613
2	2634	2654	2675	2695	2715	2736	2756	2777	2797	2818
3	2838	2858	2879	2899	2919	2940	2960	2980	3001	3021
4	3041	3062	3082	3102	3122	3143	3163	3183	3203	3224
5	3244	3264	3284	3304	3325	3345	3365	3385	3405	3425
6	3445	3465	3486	3506	3526	3546	3566	3586	3606	3626
7	3646	3666	3686	3706	3726	3746	3766	3786	3806	3826
8	3846	3866	3885	3905	3925	3945	3965	3985	4005	4025
9	4044	4064	4084	4104	4124	4143	4163	4183	4203	4223
220	34242	34262	34282	34301	34321	34341	34361	34380	34400	34420
1	4439	4459	4479	4498	4518	4537	4557	4577	4596	4616
2	4635	4655	4674	4694	4713	4733	4753	4772	4792	4811
3	4830	4850	4869	4889	4908	4928	4947	4967	4986	5005
4	5025	5044	5064	5083	5102	5122	5141	5160	5180	5199
5	5218	5238	5257	5276	5295	5315	5334	5353	5372	5392
6	5411	5430	5449	5468	5488	5507	5526	5545	5564	5583
7	5603	5622	5641	5660	5679	5698	5717	5736	5755	5774
8	5793	5813	5832	5851	5870	5889	5908	5927	5946	5965
9	5984	6003	6021	6040	6059	6078	6097	6116	6135	6154
230	36173	36192	36211	36229	36248	36267	36286	36305	36324	36342
1	6361	6380	6399	6418	6436	6455	6474	6493	6511	6530
2	6549	6568	6586	6605	6624	6642	6661	6680	6698	6717
3	6736	6754	6773	6791	6810	6829	6847	6866	6884	6903
4	6922	6940	6959	6977	6996	7014	7033	7051	7070	7088
5	7107	7125	7144	7162	7181	7199	7218	7236	7254	7273
6	7291	7310	7328	7346	7365	7383	7401	7420	7438	7457
7	7475	7493	7511	7530	7548	7566	7585	7603	7621	7639
8	7658	7676	7694	7712	7731	7749	7767	7785	7803	7822
9	7840	7858	7876	7894	7912	7931	7949	7967	7985	8003
240	38021	38039	38057	38075	38093	38112	38130	38148	38166	38184
1	8202	8220	8238	8256	8274	8292	8310	8328	8346	8364
2	8382	8399	8417	8435	8453	8471	8489	8507	8525	8543
3	8561	8578	8596	8614	8632	8650	8668	8686	8703	8721
4	8739	8757	8775	8792	8810	8828	8846	8863	8881	8899
5	8917	8934	8952	8970	8987	9005	9023	9041	9058	9076
6	9094	9111	9129	9146	9164	9182	9199	9217	9235	9252
7	9270	9287	9305	9322	9340	9358	9375	9393	9410	9428
8	9445	9463	9480	9498	9515	9533	9550	9568	9585	9602
9	9620	9637	9655	9672	9690	9707	9724	9742	9759	9777
250	39794	39811	39829	39846	39863	39881	39898	39915	39933	39950

N	0	1	2	3	4	5	6	7	8	9
250	39794	39811	39829	39846	39863	39881	39898	39915	39933	39950
1	9967	9985	40002	40019	40037	40054	40071	40088	40106	40123
2	40140	40157	0175	0192	0209	0226	0243	0261	0278	0295
3	0312	0329	0346	0364	0381	0398	0415	0432	0449	0466
4	0483	0500	0518	0535	0552	0569	0586	0603	0620	0637
5	0654	0671	0688	0705	0722	0739	0756	0773	0790	0807
6	0824	0841	0858	0875	0892	0909	0926	0943	0960	0976
7	0993	1010	1027	1044	1061	1078	1095	1111	1128	1145
8	1162	1179	1196	1212	1229	1246	1263	1280	1296	1313
9	1330	1347	1363	1380	1397	1414	1430	1447	1464	1481
260	41497	41514	41531	41547	41564	41581	41597	41614	41631	41647
1	1664	1681	1697	1714	1731	1747	1764	1780	1797	1814
2	1830	1847	1863	1880	1896	1913	1929	1946	1963	1979
3	1996	2012	2029	2045	2062	2078	2095	2111	2127	2144
4	2160	2177	2193	2210	2226	2243	2259	2275	2292	2308
5	2325	2341	2357	2374	2390	2406	2423	2439	2455	2472
6	2488	2504	2521	2537	2553	2570	2586	2602	2619	2635
7	2651	2667	2684	2700	2716	2732	2749	2765	2781	2797
8	2813	2830	2846	2862	2878	2894	2911	2927	2943	2959
9	2975	2991	3008	3024	3040	3056	3072	3088	3104	3120
270	43136	43152	43169	43185	43201	43217	43233	43249	43265	43281
1	3297	3313	3329	3345	3361	3377	3393	3409	3425	3441
2	3457	3473	3489	3505	3521	3537	3553	3569	3584	3600
3	3616	3632	3648	3664	3680	3696	3712	3727	3743	3759
4	3775	3791	3807	3823	3838	3854	3870	3886	3902	3917
5	3933	3949	3965	3981	3996	4012	4028	4044	4059	4075
6	4091	4107	4122	4138	4154	4170	4185	4201	4217	4232
7	4248	4264	4279	4295	4311	4326	4342	4358	4373	4389
8	4404	4420	4436	4451	4467	4483	4498	4514	4529	4545
9	4560	4576	4592	4607	4623	4638	4654	4669	4685	4700
280	44716	44731	44747	44762	44778	44793	44809	44824	44840	44855
1	4871	4886	4902	4917	4932	4948	4963	4979	4994	5010
2	5025	5040	5056	5071	5086	5102	5117	5133	5148	5163
3	5179	5194	5209	5225	5240	5255	5271	5286	5301	5317
4	5332	5347	5362	5378	5393	5408	5423	5439	5454	5469
5	5484	5500	5515	5530	5545	5561	5576	5591	5606	5621
6	5637	5652	5667	5682	5697	5712	5728	5743	5758	5773
7	5788	5803	5818	5834	5849	5864	5879	5894	5909	5924
8	5939	5954	5969	5984	6000	6015	6030	6045	6060	6075
9	6090	6105	6120	6135	6150	6165	6180	6195	6210	6225
290	46240	46255	46270	46285	46300	46315	46330	46345	46359	46374
1	6389	6404	6419	6434	6449	6464	6479	6494	6509	6523
2	6538	6553	6568	6583	6598	6613	6627	6642	6657	6672
3	6687	6702	6716	6731	6746	6761	6776	6790	6805	6820
4	6835	6850	6864	6879	6894	6909	6923	6938	6953	6967
5	6982	6997	7012	7026	7041	7056	7070	7085	7100	7114
6	7129	7144	7159	7173	7188	7202	7217	7232	7246	7261
7	7276	7290	7305	7319	7334	7349	7363	7378	7392	7407
8	7422	7436	7451	7465	7480	7494	7509	7524	7538	7553
9	7567	7582	7596	7611	7625	7640	7654	7669	7683	7698
300	47712	47727	47741	47756	47770	47784	47799	47813	47828	47842

N	0	1	2	3	4	5	6	7	8	9
300	47712	47727	47741	47756	47770	47784	47799	47813	47828	47842
1	7857	7871	7885	7900	7914	7929	7943	7958	7972	7986
2	8001	8015	8029	8044	8058	8073	8087	8101	8116	8130
3	8144	8159	8173	8187	8202	8216	8230	8244	8259	8273
4	8287	8302	8316	8330	8344	8359	8373	8387	8401	8416
5	8430	8444	8458	8473	8487	8501	8515	8530	8544	8558
6	8572	8586	8601	8615	8629	8643	8657	8671	8686	8700
7	8714	8728	8742	8756	8770	8785	8799	8813	8827	8841
8	8855	8869	8883	8897	8911	8926	8940	8954	8968	8982
9	8996	9010	9024	9038	9052	9066	9080	9094	9108	9122
310	49136	49150	49164	49178	49192	49206	49220	49234	49248	49262
1	9276	9290	9304	9318	9332	9346	9360	9374	9388	9402
2	9415	9429	9443	9457	9471	9485	9499	9513	9527	9541
3	9554	9568	9582	9596	9610	9624	9638	9651	9665	9679
4	9693	9707	9721	9734	9748	9762	9776	9790	9803	9817
5	9831	9845	9859	9872	9886	9900	9914	9927	9941	9955
6	9969	9982	9996	50010	50024	50037	50051	50065	50079	50092
7	50106	50120	50133	0147	0161	0174	0188	0202	0215	0229
8	0243	0256	0270	0284	0297	0311	0325	0338	0352	0365
9	0379	0393	0406	0420	0433	0447	0461	0474	0488	0501
320	50515	50529	50542	50556	50569	50583	50596	50610	50623	50637
1	0651	0664	0678	0691	0705	0718	0732	0745	0759	0772
2	0786	0799	0813	0826	0840	0853	0866	0880	0893	0907
3	0920	0934	0947	0961	0974	0987	1001	1014	1028	1041
4	1055	1068	1081	1095	1108	1121	1135	1148	1162	1175
5	1188	1202	1215	1228	1242	1255	1268	1282	1295	1308
6	1322	1335	1348	1362	1375	1388	1402	1415	1428	1441
7	1455	1468	1481	1495	1508	1521	1534	1548	1561	1574
8	1587	1601	1614	1627	1640	1654	1667	1680	1693	1706
9	1720	1733	1746	1759	1772	1786	1799	1812	1825	1838
330	51851	51865	51878	51891	51904	51917	51930	51943	51957	51970
1	1983	1996	2009	2022	2035	2048	2061	2075	2088	2101
2	2114	2127	2140	2153	2166	2179	2192	2205	2218	2231
3	2244	2257	2270	2284	2297	2310	2323	2336	2349	2362
4	2375	2388	2401	2414	2427	2440	2453	2466	2479	2492
5	2504	2517	2530	2543	2556	2569	2582	2595	2608	2621
6	2634	2647	2660	2673	2686	2699	2711	2724	2737	2750
7	2763	2776	2789	2802	2815	2827	2840	2853	2866	2879
8	2892	2905	2917	2930	2943	2956	2969	2982	2994	3007
9	3020	3033	3046	3058	3071	3084	3097	3110	3122	3135
340	53148	53161	53173	53186	53199	53212	53224	53237	53250	53263
1	3275	3288	3301	3314	3326	3339	3352	3364	3377	3390
2	3403	3415	3428	3441	3453	3466	3479	3491	3504	3517
3	3529	3542	3555	3567	3580	3593	3605	3618	3631	3643
4	3656	3668	3681	3694	3706	3719	3732	3744	3757	3769
5	3782	3794	3807	3820	3832	3845	3857	3870	3882	3895
6	3908	3920	3933	3945	3958	3970	3983	3995	4008	4020
7	4033	4045	4058	4070	4083	4095	4108	4120	4133	4145
8	4158	4170	4183	4195	4208	4220	4233	4245	4258	4270
9	4283	4295	4307	4320	4332	4345	4357	4370	4382	4394
350	54407	54419	54432	54444	54456	54469	54481	54494	54506	54518

N	0	1	2	3	4	5	6	7	8	9
350	54407	54419	54432	54444	54456	54469	54481	54494	54506	54518
1	4531	4543	4555	4568	4580	4593	4605	4617	4630	4642
2	4654	4667	4679	4691	4704	4716	4728	4741	4753	4765
3	4777	4790	4802	4814	4827	4839	4851	4864	4876	4888
4	4900	4913	4925	4937	4949	4962	4974	4986	4998	5011
5	5023	5035	5047	5060	5072	5084	5096	5108	5121	5133
6	5145	5157	5169	5182	5194	5206	5218	5230	5242	5255
7	5267	5279	5291	5303	5315	5328	5340	5352	5364	5376
8	5388	5400	5413	5425	5437	5449	5461	5473	5485	5497
9	5509	5522	5534	5546	5558	5570	5582	5594	5606	5618
360	55630	55642	55654	55666	55678	55691	55703	55715	55727	55739
1	5751	5763	5775	5787	5799	5811	5823	5835	5847	5859
2	5871	5883	5895	5907	5919	5931	5943	5955	5967	5979
3	5991	6003	6015	6027	6038	6050	6062	6074	6086	6098
4	6110	6122	6134	6146	6158	6170	6182	6194	6205	6217
5	6229	6241	6253	6265	6277	6289	6301	6312	6324	6336
6	6348	6360	6372	6384	6396	6407	6419	6431	6443	6455
7	6467	6478	6490	6502	6514	6526	6538	6549	6561	6573
8	6585	6597	6608	6620	6632	6644	6656	6667	6679	6691
9	6703	6714	6726	6738	6750	6761	6773	6785	6797	6808
370	56820	56832	56844	56855	56867	56879	56891	56902	56914	56926
1	6937	6949	6961	6972	6984	6996	7008	7019	7031	7043
2	7054	7066	7078	7089	7101	7113	7124	7136	7148	7159
3	7171	7183	7194	7206	7217	7229	7241	7252	7264	7276
4	7287	7299	7310	7322	7334	7345	7357	7368	7380	7392
5	7403	7415	7426	7438	7449	7461	7473	7484	7496	7507
6	7519	7530	7542	7553	7565	7576	7588	7600	7611	7623
7	7634	7646	7657	7669	7680	7692	7703	7715	7726	7738
8	7749	7761	7772	7784	7795	7807	7818	7830	7841	7852
9	7864	7875	7887	7898	7910	7921	7933	7944	7955	7967
380	57978	57990	58001	58013	58024	58035	58047	58058	58070	58081
1	8092	8104	8115	8127	8138	8149	8161	8172	8184	8195
2	8206	8218	8229	8240	8252	8263	8274	8286	8297	8309
3	8320	8331	8343	8354	8365	8377	8388	8399	8410	8422
4	8433	8444	8456	8467	8478	8490	8501	8512	8524	8535
5	8546	8557	8569	8580	8591	8602	8614	8625	8636	8647
6	8659	8670	8681	8692	8704	8715	8726	8737	8749	8760
7	8771	8782	8794	8805	8816	8827	8838	8850	8861	8872
8	8883	8894	8906	8917	8928	8939	8950	8961	8973	8984
9	8995	9006	9017	9028	9040	9051	9062	9073	9084	9095
390	59106	59118	59129	59140	59151	59162	59173	59184	59195	59207
1	9218	9229	9240	9251	9262	9273	9284	9295	9306	9318
2	9329	9340	9351	9362	9373	9384	9395	9406	9417	9428
3	9439	9450	9461	9472	9483	9494	9506	9517	9528	9539
4	9550	9561	9572	9583	9594	9605	9616	9627	9638	9649
5	9660	9671	9682	9693	9704	9715	9726	9737	9748	9759
6	9770	9780	9791	9802	9813	9824	9835	9846	9857	9868
7	9879	9890	9901	9912	9923	9934	9945	9956	9966	9977
8	9988	9999	60010	60021	60032	60043	60054	60065	60076	60086
9	60097	60108	0119	0130	0141	0152	0163	0173	0184	0195
400	60206	60217	60228	60239	60249	60260	60271	60282	60293	60304

N	0	1	2	3	4	5	6	7	8	9
400	60206	60217	60228	60239	60249	60260	60271	60282	60293	60304
1	0314	0325	0336	0347	0358	0369	0379	0390	0401	0412
2	0423	0433	0444	0455	0466	0477	0487	0498	0509	0520
3	0531	0541	0552	0563	0574	0584	0595	0606	0617	0627
4	0638	0649	0660	0670	0681	0692	0703	0713	0724	0735
5	0746	0756	0767	0778	0788	0799	0810	0821	0831	0842
6	0853	0863	0874	0885	0895	0906	0917	0927	0938	0949
7	0959	0970	0981	0991	1002	1013	1023	1034	1045	1055
8	1066	1077	1087	1098	1109	1119	1130	1140	1151	1162
9	1172	1183	1194	1204	1215	1225	1236	1247	1257	1268
410	61278	61289	61300	61310	61321	61331	61342	61352	61363	61374
1	1384	1395	1405	1416	1426	1437	1448	1458	1469	1479
2	1490	1500	1511	1521	1532	1542	1553	1563	1574	1584
3	1595	1606	1616	1627	1637	1648	1658	1669	1679	1690
4	1700	1711	1721	1731	1742	1752	1763	1773	1784	1794
5	1805	1815	1826	1836	1847	1857	1868	1878	1888	1899
6	1909	1920	1930	1941	1951	1962	1972	1982	1993	2003
7	2014	2024	2034	2045	2055	2066	2076	2086	2097	2107
8	2118	2128	2138	2149	2159	2170	2180	2190	2201	2211
9	2221	2232	2242	2252	2263	2273	2284	2294	2304	2315
420	62325	62335	62346	62356	62366	62377	62387	62397	62408	62418
1	2428	2439	2449	2459	2469	2480	2490	2500	2511	2521
2	2531	2542	2552	2562	2572	2583	2593	2603	2613	2624
3	2634	2644	2655	2665	2675	2685	2696	2706	2716	2726
4	2737	2747	2757	2767	2778	2788	2798	2808	2818	2829
5	2839	2849	2859	2870	2880	2890	2900	2910	2921	2931
6	2941	2951	2961	2972	2982	2992	3002	3012	3022	3033
7	3043	3053	3063	3073	3083	3094	3104	3114	3124	3134
8	3144	3155	3165	3175	3185	3195	3205	3215	3225	3236
9	3246	3256	3266	3276	3286	3296	3306	3317	3327	3337
430	63347	63357	63367	63377	63387	63397	63407	63417	63428	63438
1	3448	3458	3468	3478	3488	3498	3508	3518	3528	3538
2	3548	3558	3568	3579	3589	3599	3609	3619	3629	3639
3	3649	3659	3669	3679	3689	3699	3709	3719	3729	3739
4	3749	3759	3769	3779	3789	3799	3809	3819	3829	3839
5	3849	3859	3869	3879	3889	3899	3909	3919	3929	3939
6	3949	3959	3969	3979	3988	3998	4008	4018	4028	4038
7	4048	4058	4068	4078	4088	4098	4108	4118	4128	4137
8	4147	4157	4167	4177	4187	4197	4207	4217	4227	4237
9	4246	4256	4266	4276	4286	4296	4306	4316	4326	4335
440	64345	64355	64365	64375	64385	64395	64404	64414	64424	64434
1	4444	4454	4464	4473	4483	4493	4503	4513	4523	4532
2	4542	4552	4562	4572	4582	4591	4601	4611	4621	4631
3	4640	4650	4660	4670	4680	4689	4699	4709	4719	4729
4	4738	4748	4758	4768	4777	4787	4797	4807	4816	4826
5	4836	4846	4856	4865	4875	4885	4895	4904	4914	4924
6	4933	4943	4953	4963	4972	4982	4992	5002	5011	5021
7	5031	5040	5050	5060	5070	5079	5089	5099	5108	5118
8	5128	5137	5147	5157	5167	5176	5186	5196	5205	5215
9	5225	5234	5244	5254	5263	5273	5283	5292	5302	5312
450	65321	65331	65341	65350	65360	65369	65379	65389	65398	65408

N	0	1	2	3	4	5	6	7	8	9
450	65321	65331	65341	65350	65360	65369	65379	65389	65398	65408
1	5418	5427	5437	5447	5456	5466	5475	5485	5495	5504
2	5514	5523	5533	5543	5552	5562	5571	5581	5591	5600
3	5610	5619	5629	5639	5648	5658	5667	5677	5686	5696
4	5706	5715	5725	5734	5744	5753	5763	5772	5782	5792
5	5801	5811	5820	5830	5839	5849	5858	5868	5877	5887
6	5896	5906	5916	5925	5935	5944	5954	5963	5973	5982
7	5992	6001	6011	6020	6030	6039	6049	6058	6068	6077
8	6087	6096	6106	6115	6124	6134	6143	6153	6162	6172
9	6181	6191	6200	6210	6219	6229	6238	6247	6257	6266
460	66276	66285	66295	66304	66314	66323	66332	66342	66351	66361
1	6370	6380	6389	6398	6408	6417	6427	6436	6445	6455
2	6464	6474	6483	6492	6502	6511	6521	6530	6539	6549
3	6558	6567	6577	6586	6596	6605	6614	6624	6633	6642
4	6652	6661	6671	6680	6689	6699	6708	6717	6727	6736
5	6745	6755	6764	6773	6783	6792	6801	6811	6820	6829
6	6839	6848	6857	6867	6876	6885	6894	6904	6913	6922
7	6932	6941	6950	6960	6969	6978	6987	6997	7006	7015
8	7025	7034	7043	7052	7062	7071	7080	7089	7099	7108
9	7117	7127	7136	7145	7154	7164	7173	7182	7191	7201
470	67210	67219	67228	67237	67247	67256	67265	67274	67284	67293
1	7302	7311	7321	7330	7339	7348	7357	7367	7376	7385
2	7394	7403	7413	7422	7431	7440	7449	7459	7468	7477
3	7486	7495	7504	7514	7523	7532	7541	7550	7560	7569
4	7578	7587	7596	7605	7614	7624	7633	7642	7651	7660
5	7669	7679	7688	7697	7706	7715	7724	7733	7742	7752
6	7761	7770	7779	7788	7797	7806	7815	7825	7834	7843
7	7852	7861	7870	7879	7888	7897	7906	7916	7925	7934
8	7943	7952	7961	7970	7979	7988	7997	8006	8015	8024
9	8034	8043	8052	8061	8070	8079	8088	8097	8106	8115
480	68124	68133	68142	68151	68160	68169	68178	68187	68196	68205
1	8215	8224	8233	8242	8251	8260	8269	8278	8287	8296
2	8305	8314	8323	8332	8341	8350	8359	8368	8377	8386
3	8395	8404	8413	8422	8431	8440	8449	8458	8467	8476
4	8485	8494	8502	8511	8520	8529	8538	8547	8556	8565
5	8574	8583	8592	8601	8610	8619	8628	8637	8646	8655
6	8664	8673	8681	8690	8699	8708	8717	8726	8735	8744
7	8753	8762	8771	8780	8789	8797	8806	8815	8824	8833
8	8842	8851	8860	8869	8878	8886	8895	8904	8913	8922
9	8931	8940	8949	8958	8966	8975	8984	8993	9002	9011
490	69020	69028	69037	69046	69055	69064	69073	69082	69090	69099
1	9108	9117	9126	9135	9144	9152	9161	9170	9179	9188
2	9197	9205	9214	9223	9232	9241	9249	9258	9267	9276
3	9285	9294	9302	9311	9320	9329	9338	9346	9355	9364
4	9373	9381	9390	9399	9408	9417	9425	9434	9443	9452
5	9461	9469	9478	9487	9496	9504	9513	9522	9531	9539
6	9548	9557	9566	9574	9583	9592	9601	9609	9618	9627
7	9636	9644	9653	9662	9671	9679	9688	9697	9705	9714
8	9723	9732	9740	9749	9758	9767	9775	9784	9793	9801
9	9810	9819	9827	9836	9845	9854	9862	9871	9880	9888
500	69897	69906	69914	69923	69932	69940	69949	69958	69966	69975

N	0	1	2	3	4	5	6	7	8	9
500	69897	69906	69914	69923	69932	69940	69949	69958	69966	69975
1	9984	9992	70001	70010	70018	70027	70036	70044	70053	70062
2	70070	70079	0088	0096	0105	0114	0122	0131	0140	0148
3	0157	0165	0174	0183	0191	0200	0209	0217	0226	0234
4	0243	0252	0260	0269	0278	0286	0295	0303	0312	0321
5	0329	0338	0346	0355	0364	0372	0381	0389	0398	0406
6	0415	0424	0432	0441	0449	0458	0467	0475	0484	0492
7	0501	0509	0518	0526	0535	0544	0552	0561	0569	0578
8	0586	0595	0603	0612	0621	0629	0638	0646	0655	0663
9	0672	0680	0689	0697	0706	0714	0723	0731	0740	0749
510	70757	70766	70774	70783	70791	70800	70808	70817	70825	70834
1	0842	0851	0859	0868	0876	0885	0893	0902	0910	0919
2	0927	0935	0944	0952	0961	0969	0978	0986	0995	1003
3	1012	1020	1029	1037	1046	1054	1063	1071	1079	1088
4	1096	1105	1113	1122	1130	1139	1147	1155	1164	1172
5	1181	1189	1198	1206	1214	1223	1231	1240	1248	1257
6	1265	1273	1282	1290	1299	1307	1315	1324	1332	1341
7	1349	1357	1366	1374	1383	1391	1399	1408	1416	1425
8	1433	1441	1450	1458	1466	1475	1483	1492	1500	1508
9	1517	1525	1533	1542	1550	1559	1567	1575	1584	1592
520	71600	71609	71617	71625	71634	71642	71650	71659	71667	71675
1	1684	1692	1700	1709	1717	1725	1734	1742	1750	1759
2	1767	1775	1784	1792	1800	1809	1817	1825	1834	1842
3	1850	1858	1867	1875	1883	1892	1900	1908	1917	1925
4	1933	1941	1950	1958	1966	1975	1983	1991	1999	2008
5	2016	2024	2032	2041	2049	2057	2066	2074	2082	2090
6	2099	2107	2115	2123	2132	2140	2148	2156	2165	2173
7	2181	2189	2198	2206	2214	2222	2230	2239	2247	2255
8	2263	2272	2280	2288	2296	2304	2313	2321	2329	2337
9	2346	2354	2362	2370	2378	2387	2395	2403	2411	2419
530	72428	72436	72444	72452	72460	72469	72477	72485	72493	72501
1	2509	2518	2526	2534	2542	2550	2558	2567	2575	2583
2	2591	2599	2607	2616	2624	2632	2640	2648	2656	2665
3	2673	2681	2689	2697	2705	2713	2722	2730	2738	2746
4	2754	2762	2770	2779	2787	2795	2803	2811	2819	2827
5	2835	2843	2852	2860	2868	2876	2884	2892	2900	2908
6	2916	2925	2933	2941	2949	2957	2965	2973	2981	2989
7	2997	3006	3014	3022	3030	3038	3046	3054	3062	3070
8	3078	3086	3094	3102	3111	3119	3127	3135	3143	3151
9	3159	3167	3175	3183	3191	3199	3207	3215	3223	3231
540	73239	73247	73255	73263	73272	73280	73288	73296	73304	73312
1	3320	3328	3336	3344	3352	3360	3368	3376	3384	3392
2	3400	3408	3416	3424	3432	3440	3448	3456	3464	3472
3	3480	3488	3496	3504	3512	3520	3528	3536	3544	3552
4	3560	3568	3576	3584	3592	3600	3608	3616	3624	3632
5	3640	3648	3656	3664	3672	3679	3687	3695	3703	3711
6	3719	3727	3735	3743	3751	3759	3767	3775	3783	3791
7	3799	3807	3815	3823	3830	3838	3846	3854	3862	3870
8	3878	3886	3894	3902	3910	3918	3926	3933	3941	3949
9	3957	3965	3973	3981	3989	3997	4005	4013	4020	4028
550	74036	74044	74052	74060	74068	74076	74084	74092	74099	74107

N	0	1	2	3	4	5	6	7	8	9
550	74036	74044	74052	74060	74068	74076	74084	74092	74099	74107
1	4115	4123	4131	4139	4147	4155	4162	4170	4178	4186
2	4194	4202	4210	4218	4225	4233	4241	4249	4257	4265
3	4273	4280	4288	4296	4304	4312	4320	4327	4335	4343
4	4351	4359	4367	4374	4382	4390	4398	4406	4414	4421
5	4429	4437	4445	4453	4461	4468	4476	4484	4492	4500
6	4507	4515	4523	4531	4539	4547	4554	4562	4570	4578
7	4586	4593	4601	4609	4617	4624	4632	4640	4648	4656
8	4663	4671	4679	4687	4695	4702	4710	4718	4726	4733
9	4741	4749	4757	4764	4772	4780	4788	4796	4803	4811
560	74819	74827	74834	74842	74850	74858	74865	74873	74881	74889
1	4896	4904	4912	4920	4927	4935	4943	4950	4958	4966
2	4974	4981	4989	4997	5005	5012	5020	5028	5035	5043
3	5051	5059	5066	5074	5082	5089	5097	5105	5113	5120
4	5128	5136	5143	5151	5159	5166	5174	5182	5189	5197
5	5205	5213	5220	5228	5236	5243	5251	5259	5266	5274
6	5282	5289	5297	5305	5312	5320	5328	5335	5343	5351
7	5358	5366	5374	5381	5389	5397	5404	5412	5420	5427
8	5435	5442	5450	5458	5465	5473	5481	5488	5496	5504
9	5511	5519	5526	5534	5542	5549	5557	5565	5572	5580
570	75587	75595	75603	75610	75618	75626	75633	75641	75648	75656
1	5664	5671	5679	5686	5694	5702	5709	5717	5724	5732
2	5740	5747	5755	5762	5770	5778	5785	5793	5800	5808
3	5815	5823	5831	5838	5846	5853	5861	5868	5876	5884
4	5891	5899	5906	5914	5921	5929	5937	5944	5952	5959
5	5967	5974	5982	5989	5997	6005	6012	6020	6027	6035
6	6042	6050	6057	6065	6072	6080	6087	6095	6103	6110
7	6118	6125	6133	6140	6148	6155	6163	6170	6178	6185
8	6193	6200	6208	6215	6223	6230	6238	6245	6253	6260
9	6268	6275	6283	6290	6298	6305	6313	6320	6328	6335
580	76343	76350	76358	76365	76373	76380	76388	76395	76403	76410
1	6418	6425	6433	6440	6448	6455	6462	6470	6477	6485
2	6492	6500	6507	6515	6522	6530	6537	6545	6552	6559
3	6567	6574	6582	6589	6597	6604	6612	6619	6626	6634
4	6641	6649	6656	6664	6671	6678	6686	6693	6701	6708
5	6716	6723	6730	6738	6745	6753	6760	6768	6775	6782
6	6790	6797	6805	6812	6819	6827	6834	6842	6849	6856
7	6864	6871	6879	6886	6893	6901	6908	6916	6923	6930
8	6938	6945	6953	6960	6967	6975	6982	6989	6997	7004
9	7012	7019	7026	7034	7041	7048	7056	7063	7070	7078
590	77085	77093	77100	77107	77115	77122	77129	77137	77144	77151
1	7159	7166	7173	7181	7188	7195	7203	7210	7217	7225
2	7232	7240	7247	7254	7262	7269	7276	7283	7291	7298
3	7305	7313	7320	7327	7335	7342	7349	7357	7364	7371
4	7379	7386	7393	7401	7408	7415	7422	7430	7437	7444
5	7452	7459	7466	7474	7481	7488	7495	7503	7510	7517
6	7525	7532	7539	7546	7554	7561	7568	7576	7583	7590
7	7597	7605	7612	7619	7627	7634	7641	7648	7656	7663
8	7670	7677	7685	7692	7699	7706	7714	7721	7728	7735
9	7743	7750	7757	7764	7772	7779	7786	7793	7801	7808
600	77815	77822	77830	77837	77844	77851	77859	77866	77873	77880

N	0	1	2	3	4	5	6	7	8	9
600	77815	77822	77830	77837	77844	77851	77859	77866	77873	77880
1	7887	7895	7902	7909	7916	7924	7931	7938	7945	7952
2	7960	7967	7974	7981	7988	7996	8003	8010	8017	8025
3	8032	8039	8046	8053	8061	8068	8075	8082	8089	8097
4	8104	8111	8118	8125	8132	8140	8147	8154	8161	8168
5	8176	8183	8190	8197	8204	8211	8219	8226	8233	8240
6	8247	8254	8262	8269	8276	8283	8290	8297	8305	8312
7	8319	8326	8333	8340	8347	8355	8362	8369	8376	8383
8	8390	8398	8405	8412	8419	8426	8433	8440	8447	8455
9	8462	8469	8476	8483	8490	8497	8504	8512	8519	8526
610	78533	78540	78547	78554	78561	78569	78576	78583	78590	78597
1	8604	8611	8618	8625	8633	8640	8647	8654	8661	8668
2	8675	8682	8689	8696	8704	8711	8718	8725	8732	8739
3	8746	8753	8760	8767	8774	8781	8789	8796	8803	8810
4	8817	8824	8831	8838	8845	8852	8859	8866	8873	8880
5	8888	8895	8902	8909	8916	8923	8930	8937	8944	8951
6	8958	8965	8972	8979	8986	8993	9000	9007	9014	9021
7	9029	9036	9043	9050	9057	9064	9071	9078	9085	9092
8	9099	9106	9113	9120	9127	9134	9141	9148	9155	9162
9	9169	9176	9183	9190	9197	9204	9211	9218	9225	9232
620	79239	79246	79253	79260	79267	79274	79281	79288	79295	79302
1	9309	9316	9323	9330	9337	9344	9351	9358	9365	9372
2	9379	9386	9393	9400	9407	9414	9421	9428	9435	9442
3	9449	9456	9463	9470	9477	9484	9491	9498	9505	9511
4	9518	9525	9532	9539	9546	9553	9560	9567	9574	9581
5	9588	9595	9602	9609	9616	9623	9630	9637	9644	9650
6	9657	9664	9671	9678	9685	9692	9699	9706	9713	9720
7	9727	9734	9741	9748	9754	9761	9768	9775	9782	9789
8	9796	9803	9810	9817	9824	9831	9837	9844	9851	9858
9	9865	9872	9879	9886	9893	9900	9906	9913	9920	9927
630	79934	79941	79948	79955	79962	79969	79975	79982	79989	79996
1	80003	80010	80017	80024	80030	80037	80044	80051	80058	80065
2	0072	0079	0085	0092	0099	0106	0113	0120	0127	0134
3	0140	0147	0154	0161	0168	0175	0182	0188	0195	0202
4	0209	0216	0223	0229	0236	0243	0250	0257	0264	0271
5	0277	0284	0291	0298	0305	0312	0318	0325	0332	0339
6	0346	0353	0359	0366	0373	0380	0387	0393	0400	0407
7	0414	0421	0428	0434	0441	0448	0455	0462	0468	0475
8	0482	0489	0496	0502	0509	0516	0523	0530	0536	0543
9	0550	0557	0564	0570	0577	0584	0591	0598	0604	0611
640	80618	80625	80632	80638	80645	80652	80659	80665	80672	80679
1	0686	0693	0699	0706	0713	0720	0726	0733	0740	0747
2	0754	0760	0767	0774	0781	0787	0794	0801	0808	0814
3	0821	0828	0835	0841	0848	0855	0862	0868	0875	0882
4	0889	0895	0902	0909	0916	0922	0929	0936	0943	0949
5	0956	0963	0969	0976	0983	0990	0996	1003	1010	1017
6	1023	1030	1037	1043	1050	1057	1064	1070	1077	1084
7	1090	1097	1104	1111	1117	1124	1131	1137	1144	1151
8	1158	1164	1171	1178	1184	1191	1198	1204	1211	1218
9	1224	1231	1238	1245	1251	1258	1265	1271	1278	1285
650	81291	81298	81305	81311	81318	81325	81331	81338	81345	81351

N	0	1	2	3	4	5	6	7	8	9
650	81291	81298	81305	81311	81318	81325	81331	81338	81345	81351
1	1358	1365	1371	1378	1385	1391	1398	1405	1411	1418
2	1425	1431	1438	1445	1451	1458	1465	1471	1478	1485
3	1491	1498	1505	1511	1518	1525	1531	1538	1544	1551
4	1558	1564	1571	1578	1584	1591	1598	1604	1611	1617
5	1624	1631	1637	1644	1651	1657	1664	1671	1677	1684
6	1690	1697	1704	1710	1717	1723	1730	1737	1743	1750
7	1757	1763	1770	1776	1783	1790	1796	1803	1809	1816
8	1823	1829	1836	1842	1849	1856	1862	1869	1875	1882
9	1889	1895	1902	1908	1915	1921	1928	1935	1941	1948
660	81954	81961	81968	81974	81981	81987	81994	82000	82007	82014
1	2020	2027	2033	2040	2046	2053	2060	2066	2073	2079
2	2086	2092	2099	2105	2112	2119	2125	2132	2138	2145
3	2151	2158	2164	2171	2178	2184	2191	2197	2204	2210
4	2217	2223	2230	2236	2243	2249	2256	2263	2269	2276
5	2282	2289	2295	2302	2308	2315	2321	2328	2334	2341
6	2347	2354	2360	2367	2373	2380	2387	2393	2400	2406
7	2413	2419	2426	2432	2439	2445	2452	2458	2465	2471
8	2478	2484	2491	2497	2504	2510	2517	2523	2530	2536
9	2543	2549	2556	2562	2569	2575	2582	2588	2595	2601
670	82607	82614	82620	82627	82633	82640	82646	82653	82659	82666
1	2672	2679	2685	2692	2698	2705	2711	2718	2724	2730
2	2737	2743	2750	2756	2763	2769	2776	2782	2789	2795
3	2802	2808	2814	2821	2827	2834	2840	2847	2853	2860
4	2866	2872	2879	2885	2892	2898	2905	2911	2918	2924
5	2930	2937	2943	2950	2956	2963	2969	2975	2982	2988
6	2995	3001	3008	3014	3020	3027	3033	3040	3046	3052
7	3059	3065	3072	3078	3085	3091	3097	3104	3110	3117
8	3123	3129	3136	3142	3149	3155	3161	3168	3174	3181
9	3187	3193	3200	3206	3213	3219	3225	3232	3238	3245
680	83251	83257	83264	83270	83276	83283	83289	83296	83302	83308
1	3315	3321	3327	3334	3340	3347	3353	3359	3366	3372
2	3378	3385	3391	3398	3404	3410	3417	3423	3429	3436
3	3442	3448	3455	3461	3467	3474	3480	3487	3493	3499
4	3506	3512	3518	3525	3531	3537	3544	3550	3556	3563
5	3569	3575	3582	3588	3594	3601	3607	3613	3620	3626
6	3632	3639	3645	3651	3658	3664	3670	3677	3683	3689
7	3696	3702	3708	3715	3721	3727	3734	3740	3746	3753
8	3759	3765	3771	3778	3784	3790	3797	3803	3809	3816
9	3822	3828	3835	3841	3847	3853	3860	3866	3872	3879
690	83885	83891	83897	83904	83910	83916	83923	83929	83935	83942
1	3948	3954	3960	3967	3973	3979	3985	3992	3998	4004
2	4011	4017	4023	4029	4036	4042	4048	4055	4061	4067
3	4073	4080	4086	4092	4098	4105	4111	4117	4123	4130
4	4136	4142	4148	4155	4161	4167	4173	4180	4186	4192
5	4198	4205	4211	4217	4223	4230	4236	4242	4248	4255
6	4261	4267	4273	4280	4286	4292	4298	4305	4311	4317
7	4323	4330	4336	4342	4348	4354	4361	4367	4373	4379
8	4386	4392	4398	4404	4410	4417	4423	4429	4435	4442
9	4448	4454	4460	4466	4473	4479	4485	4491	4497	4504
700	84510	84516	84522	84528	84535	84541	84547	84553	84559	84566

N	0	1	2	3	4	5	6	7	8	9
700	84510	84516	84522	84528	84535	84541	84547	84553	84559	84566
1	4572	4578	4584	4590	4597	4603	4609	4615	4621	4628
2	4634	4640	4646	4652	4658	4665	4671	4677	4683	4689
3	4696	4702	4708	4714	4720	4726	4733	4739	4745	4751
4	4757	4763	4770	4776	4782	4788	4794	4800	4807	4813
5	4819	4825	4831	4837	4844	4850	4856	4862	4868	4874
6	4880	4887	4893	4899	4905	4911	4917	4924	4930	4936
7	4942	4948	4954	4960	4967	4973	4979	4985	4991	4997
8	5003	5009	5016	5022	5028	5034	5040	5046	5052	5058
9	5065	5071	5077	5083	5089	5095	5101	5107	5114	5120
710	85126	85132	85138	85144	85150	85156	85163	85169	85175	85181
1	5187	5193	5199	5205	5211	5217	5224	5230	5236	5242
2	5248	5254	5260	5266	5272	5278	5285	5291	5297	5303
3	5309	5315	5321	5327	5333	5339	5345	5352	5358	5364
4	5370	5376	5382	5388	5394	5400	5406	5412	5418	5425
5	5431	5437	5443	5449	5455	5461	5467	5473	5479	5485
6	5491	5497	5503	5509	5516	5522	5528	5534	5540	5546
7	5552	5558	5564	5570	5576	5582	5588	5594	5600	5606
8	5612	5618	5625	5631	5637	5643	5649	5655	5661	5667
9	5673	5679	5685	5691	5697	5703	5709	5715	5721	5727
720	85733	85739	85745	85751	85757	85763	85769	85775	85781	85788
1	5794	5800	5806	5812	5818	5824	5830	5836	5842	5848
2	5854	5860	5866	5872	5878	5884	5890	5896	5902	5908
3	5914	5920	5926	5932	5938	5944	5950	5956	5962	5968
4	5974	5980	5986	5992	5998	6004	6010	6016	6022	6028
5	6034	6040	6046	6052	6058	6064	6070	6076	6082	6088
6	6094	6100	6106	6112	6118	6124	6130	6136	6141	6147
7	6153	6159	6165	6171	6177	6183	6189	6195	6201	6207
8	6213	6219	6225	6231	6237	6243	6249	6255	6261	6267
9	6273	6279	6285	6291	6297	6303	6308	6314	6320	6326
730	86332	86338	86344	86350	86356	86362	86368	86374	86380	86386
1	6392	6398	6404	6410	6415	6421	6427	6433	6439	6445
2	6451	6457	6463	6469	6475	6481	6487	6493	6499	6504
3	6510	6516	6522	6528	6534	6540	6546	6552	6558	6564
4	6570	6576	6581	6587	6593	6599	6605	6611	6617	6623
5	6629	6635	6641	6646	6652	6658	6664	6670	6676	6682
6	6688	6694	6700	6705	6711	6717	6723	6729	6735	6741
7	6747	6753	6759	6764	6770	6776	6782	6788	6794	6800
8	6806	6812	6817	6823	6829	6835	6841	6847	6853	6859
9	6864	6870	6876	6882	6888	6894	6900	6906	6911	6917
740	86923	86929	86935	86941	86947	86953	86958	86964	86970	86976
1	6982	6988	6994	6999	7005	7011	7017	7023	7029	7035
2	7040	7046	7052	7058	7064	7070	7075	7081	7087	7093
3	7099	7105	7111	7116	7122	7128	7134	7140	7146	7151
4	7157	7163	7169	7175	7181	7186	7192	7198	7204	7210
5	7216	7221	7227	7233	7239	7245	7251	7256	7262	7268
6	7274	7280	7286	7291	7297	7303	7309	7315	7320	7326
7	7332	7338	7344	7349	7355	7361	7367	7373	7379	7384
8	7390	7396	7402	7408	7413	7419	7425	7431	7437	7442
9	7448	7454	7460	7466	7471	7477	7483	7489	7495	7500
750	87506	87512	87518	87523	87529	87535	87541	87547	87552	875[illegible]

N	0	1	2	3	4	5	6	7	8	9
750	87506	87512	87518	87523	87529	87535	87541	87547	87552	87558
1	7564	7570	7576	7581	7587	7593	7599	7604	7610	7616
2	7622	7628	7633	7639	7645	7651	7656	7662	7668	7674
3	7679	7685	7691	7697	7703	7708	7714	7720	7726	7731
4	7737	7743	7749	7754	7760	7766	7772	7777	7783	7789
5	7795	7800	7806	7812	7818	7823	7829	7835	7841	7846
6	7852	7858	7864	7869	7875	7881	7887	7892	7898	7904
7	7910	7915	7921	7927	7933	7938	7944	7950	7955	7961
8	7967	7973	7978	7984	7990	7996	8001	8007	8013	8018
9	8024	8030	8036	8041	8047	8053	8058	8064	8070	8076
760	88081	88087	88093	88098	88104	88110	88116	88121	88127	88133
1	8138	8144	8150	8156	8161	8167	8173	8178	8184	8190
2	8195	8201	8207	8213	8218	8224	8230	8235	8241	8247
3	8252	8258	8264	8270	8275	8281	8287	8292	8298	8304
4	8309	8315	8321	8326	8332	8338	8343	8349	8355	8360
5	8366	8372	8377	8383	8389	8395	8400	8406	8412	8417
6	8423	8429	8434	8440	8446	8451	8457	8463	8468	8474
7	8480	8485	8491	8497	8502	8508	8513	8519	8525	8530
8	8536	8542	8547	8553	8559	8564	8570	8576	8581	8587
9	8593	8598	8604	8610	8615	8621	8627	8632	8638	8643
770	88649	88655	88660	88666	88672	88677	88683	88689	88694	88700
1	8705	8711	8717	8722	8728	8734	8739	8745	8750	8756
2	8762	8767	8773	8779	8784	8790	8795	8801	8807	8812
3	8818	8824	8829	8835	8840	8846	8852	8857	8863	8868
4	8874	8880	8885	8891	8897	8902	8908	8913	8919	8925
5	8930	8936	8941	8947	8953	8958	8964	8969	8975	8981
6	8986	8992	8997	9003	9009	9014	9020	9025	9031	9037
7	9042	9048	9053	9059	9064	9070	9076	9081	9087	9092
8	9098	9104	9109	9115	9120	9126	9131	9137	9143	9148
9	9154	9159	9165	9170	9176	9182	9187	9193	9198	9204
780	89209	89215	89221	89226	89232	89237	89243	89248	89254	89260
1	9265	9271	9276	9282	9287	9293	9298	9304	9310	9315
2	9321	9326	9332	9337	9343	9348	9354	9360	9365	9371
3	9376	9382	9387	9393	9398	9404	9409	9415	9421	9426
4	9432	9437	9443	9448	9454	9459	9465	9470	9476	9481
5	9487	9492	9498	9504	9509	9515	9520	9526	9531	9537
6	9542	9548	9553	9559	9564	9570	9575	9581	9586	9592
7	9597	9603	9609	9614	9620	9625	9631	9636	9642	9647
8	9653	9658	9664	9669	9675	9680	9686	9691	9697	9702
9	9708	9713	9719	9724	9730	9735	9741	9746	9752	9757
790	89763	89768	89774	89779	89785	89790	89796	89801	89807	89812
1	9818	9823	9829	9834	9840	9845	9851	9856	9862	9867
2	9873	9878	9883	9889	9894	9900	9905	9911	9916	9922
3	9927	9933	9938	9944	9949	9955	9960	9966	9971	9977
4	9982	9988	9993	9998	90004	90009	90015	90020	90026	90031
5	90037	90042	90048	90053	0059	0064	0069	0075	0080	0086
6	0091	0097	0102	0108	0113	0119	0124	0129	0135	0140
7	0146	0151	0157	0162	0168	0173	0179	0184	0189	0195
8	0200	0206	0211	0217	0222	0227	0233	0238	0244	0249
9	0255	0260	0266	0271	0276	0282	0287	0293	0298	0304
800	90309	90314	90320	90325	90331	90336	90342	90347	90352	90358

N	0	1	2	3	4	5	6	7	8	9
800	90309	90314	90320	90325	90331	90336	90342	90347	90352	90358
1	0363	0369	0374	0380	0385	0390	0396	0401	0407	0412
2	0417	0423	0428	0434	0439	0445	0450	0455	0461	0466
3	0472	0477	0482	0488	0493	0499	0504	0509	0515	0520
4	0526	0531	0536	0542	0547	0553	0558	0563	0569	0574
5	0580	0585	0590	0596	0601	0607	0612	0617	0623	0628
6	0634	0639	0644	0650	0655	0660	0666	0671	0677	0682
7	0687	0693	0698	0703	0709	0714	0720	0725	0730	0736
8	0741	0747	0752	0757	0763	0768	0773	0779	0784	0789
9	0795	0800	0806	0811	0816	0822	0827	0832	0838	0843
810	90849	90854	90859	90865	90870	90875	90881	90886	90891	90897
1	0902	0907	0913	0918	0924	0929	0934	0940	0945	0950
2	0956	0961	0966	0972	0977	0982	0988	0993	0998	1004
3	1009	1014	1020	1025	1030	1036	1041	1046	1052	1057
4	1062	1068	1073	1078	1084	1089	1094	1100	1105	1110
5	1116	1121	1126	1132	1137	1142	1148	1153	1158	1164
6	1169	1174	1180	1185	1190	1196	1201	1206	1212	1217
7	1222	1228	1233	1238	1243	1249	1254	1259	1265	1270
8	1275	1281	1286	1291	1297	1302	1307	1312	1318	1323
9	1328	1334	1339	1344	1350	1355	1360	1365	1371	1376
820	91381	91387	91392	91397	91403	91408	91413	91418	91424	91429
1	1434	1440	1445	1450	1455	1461	1466	1471	1477	1482
2	1487	1492	1498	1503	1508	1514	1519	1524	1529	1535
3	1540	1545	1551	1556	1561	1566	1572	1577	1582	1587
4	1593	1598	1603	1609	1614	1619	1624	1630	1635	1640
5	1645	1651	1656	1661	1666	1672	1677	1682	1687	1693
6	1698	1703	1709	1714	1719	1724	1730	1735	1740	1745
7	1751	1756	1761	1766	1772	1777	1782	1787	1793	1798
8	1803	1808	1814	1819	1824	1829	1834	1840	1845	1850
9	1855	1861	1866	1871	1876	1882	1887	1892	1897	1903
830	91908	91913	91918	91924	91929	91934	91939	91944	91950	91955
1	1960	1965	1971	1976	1981	1986	1991	1997	2002	2007
2	2012	2018	2023	2028	2033	2038	2044	2049	2054	2059
3	2065	2070	2075	2080	2085	2091	2096	2101	2106	2111
4	2117	2122	2127	2132	2137	2143	2148	2153	2158	2163
5	2169	2174	2179	2184	2189	2195	2200	2205	2210	2215
6	2221	2226	2231	2236	2241	2247	2252	2257	2262	2267
7	2273	2278	2283	2288	2293	2298	2304	2309	2314	2319
8	2324	2330	2335	2340	2345	2350	2355	2361	2366	2371
9	2376	2381	2387	2392	2397	2402	2407	2412	2418	2423
840	92428	92433	92438	92443	92449	92454	92459	92464	92469	92474
1	2480	2485	2490	2495	2500	2505	2511	2516	2521	2526
2	2531	2536	2542	2547	2552	2557	2562	2567	2572	2578
3	2583	2588	2593	2598	2603	2609	2614	2619	2624	2629
4	2634	2639	2645	2650	2655	2660	2665	2670	2675	2681
5	2686	2691	2696	2701	2706	2711	2716	2722	2727	2732
6	2737	2742	2747	2752	2758	2763	2768	2773	2778	2783
7	2788	2793	2799	2804	2809	2814	2819	2824	2829	2834
8	2840	2845	2850	2855	2860	2865	2870	2875	2881	2886
9	2891	2896	2901	2906	2911	2916	2921	2927	2932	2937
850	92942	92947	92952	92957	92962	92967	92973	92978	92983	92988

N	0	1	2	3	4	5	6	7	8	9
850	92942	92947	92952	92957	92962	92967	92973	92978	92983	92988
1	2993	2998	3003	3008	3013	3018	3024	3029	3034	3039
2	3044	3049	3054	3059	3064	3069	3075	3080	3085	3090
3	3095	3100	3105	3110	3115	3120	3125	3131	3136	3141
4	3146	3151	3156	3161	3166	3171	3176	3181	3186	3192
5	3197	3202	3207	3212	3217	3222	3227	3232	3237	3242
6	3247	3252	3258	3263	3268	3273	3278	3283	3288	3293
7	3298	3303	3308	3313	3318	3323	3328	3334	3339	3344
8	3349	3354	3359	3364	3369	3374	3379	3384	3389	3394
9	3399	3404	3409	3414	3420	3425	3430	3435	3440	3445
860	93450	93455	93460	93465	93470	93475	93480	93485	93490	93495
1	3500	3505	3510	3515	3520	3526	3531	3536	3541	3546
2	3551	3556	3561	3566	3571	3576	3581	3586	3591	3596
3	3601	3606	3611	3616	3621	3626	3631	3636	3641	3646
4	3651	3656	3661	3666	3671	3676	3682	3687	3692	3697
5	3702	3707	3712	3717	3722	3727	3732	3737	3742	3747
6	3752	3757	3762	3767	3772	3777	3782	3787	3792	3797
7	3802	3807	3812	3817	3822	3827	3832	3837	3842	3847
8	3852	3857	3862	3867	3872	3877	3882	3887	3892	3897
9	3902	3907	3912	3917	3922	3927	3932	3937	3942	3947
870	93952	93957	93962	93967	93972	93977	93982	93987	93992	93997
1	4002	4007	4012	4017	4022	4027	4032	4037	4042	4047
2	4052	4057	4062	4067	4072	4077	4082	4086	4091	4096
3	4101	4106	4111	4116	4121	4126	4131	4136	4141	4146
4	4151	4156	4161	4166	4171	4176	4181	4186	4191	4196
5	4201	4206	4211	4216	4221	4226	4231	4236	4240	4245
6	4250	4255	4260	4265	4270	4275	4280	4285	4290	4295
7	4300	4305	4310	4315	4320	4325	4330	4335	4340	4345
8	4349	4354	4359	4364	4369	4374	4379	4384	4389	4394
9	4399	4404	4409	4414	4419	4424	4429	4433	4438	4443
880	94448	94453	94458	94463	94468	94473	94478	94483	94488	94493
1	4498	4503	4507	4512	4517	4522	4527	4532	4537	4542
2	4547	4552	4557	4562	4567	4571	4576	4581	4586	4591
3	4596	4601	4606	4611	4616	4621	4626	4630	4635	4640
4	4645	4650	4655	4660	4665	4670	4675	4680	4685	4689
5	4694	4699	4704	4709	4714	4719	4724	4729	4734	4738
6	4743	4748	4753	4758	4763	4768	4773	4778	4783	4787
7	4792	4797	4802	4807	4812	4817	4822	4827	4832	4836
8	4841	4846	4851	4856	4861	4866	4871	4876	4880	4885
9	4890	4895	4900	4905	4910	4915	4919	4924	4929	4934
890	94939	94944	94949	94954	94959	94963	94968	94973	94978	94983
1	4988	4993	4998	5002	5007	5012	5017	5022	5027	5032
2	5036	5041	5046	5051	5056	5061	5066	5071	5075	5080
3	5085	5090	5095	5100	5105	5109	5114	5119	5124	5129
4	5134	5139	5143	5148	5153	5158	5163	5168	5173	5177
5	5182	5187	5192	5197	5202	5207	5211	5216	5221	5226
6	5231	5236	5240	5245	5250	5255	5260	5265	5270	5274
7	5279	5284	5289	5294	5299	5303	5308	5313	5318	5323
8	5328	5332	5337	5342	5347	5352	5357	5361	5366	5371
9	5376	5381	5386	5390	5395	5400	5405	5410	5415	5419
900	95424	95429	95434	95439	95444	95448	95453	95458	95463	95468

N	0	1	2	3	4	5	6	7	8	9
900	95424	95429	95434	95439	95444	95448	95453	95458	95463	95468
1	5472	5477	5482	5487	5492	5497	5501	5506	5511	5516
2	5521	5525	5530	5535	5540	5545	5550	5554	5559	5564
3	5569	5574	5578	5583	5588	5593	5598	5602	5607	5612
4	5617	5622	5626	5631	5636	5641	5646	5650	5655	5660
5	5665	5670	5674	5679	5684	5689	5694	5698	5703	5708
6	5713	5718	5722	5727	5732	5737	5742	5746	5751	5756
7	5761	5766	5770	5775	5780	5785	5789	5794	5799	5804
8	5809	5813	5818	5823	5828	5832	5837	5842	5847	5852
9	5856	5861	5866	5871	5875	5880	5885	5890	5895	5899
910	95904	95909	95914	95918	95923	95928	95933	95938	95942	95947
1	5952	5957	5961	5966	5971	5976	5980	5985	5990	5995
2	5999	6004	6009	6014	6019	6023	6028	6033	6038	6042
3	6047	6052	6057	6061	6066	6071	6076	6080	6085	6090
4	6095	6099	6104	6109	6114	6118	6123	6128	6133	6137
5	6142	6147	6152	6156	6161	6166	6171	6175	6180	6185
6	6190	6194	6199	6204	6209	6213	6218	6223	6227	6232
7	6237	6242	6246	6251	6256	6261	6265	6270	6275	6280
8	6284	6289	6294	6298	6303	6308	6313	6317	6322	6327
9	6332	6336	6341	6346	6350	6355	6360	6365	6369	6374
920	96379	96384	96388	96393	96398	96402	96407	96412	96417	96421
1	6426	6431	6435	6440	6445	6450	6454	6459	6464	6468
2	6473	6478	6483	6487	6492	6497	6501	6506	6511	6515
3	6520	6525	6530	6534	6539	6544	6548	6553	6558	6562
4	6567	6572	6577	6581	6586	6591	6595	6600	6605	6609
5	6614	6619	6624	6628	6633	6638	6642	6647	6652	6656
6	6661	6666	6670	6675	6680	6685	6689	6694	6699	6703
7	6708	6713	6717	6722	6727	6731	6736	6741	6745	6750
8	6755	6759	6764	6769	6774	6778	6783	6788	6792	6797
9	6802	6806	6811	6816	6820	6825	6830	6834	6839	6844
930	96848	96853	96858	96862	96867	96872	96876	96881	96886	96890
1	6895	6900	6904	6909	6914	6918	6923	6928	6932	6937
2	6942	6946	6951	6956	6960	6965	6970	6974	6979	6984
3	6988	6993	6997	7002	7007	7011	7016	7021	7025	7030
4	7035	7039	7044	7049	7053	7058	7063	7067	7072	7077
5	7081	7086	7090	7095	7100	7104	7109	7114	7118	7123
6	7128	7132	7137	7142	7146	7151	7155	7160	7165	7169
7	7174	7179	7183	7188	7192	7197	7202	7206	7211	7216
8	7220	7225	7230	7234	7239	7243	7248	7253	7257	7262
9	7267	7271	7276	7280	7285	7290	7294	7299	7304	7308
940	97313	97317	97322	97327	97331	97336	97340	97345	97350	97354
1	7359	7364	7368	7373	7377	7382	7387	7391	7396	7400
2	7405	7410	7414	7419	7424	7428	7433	7437	7442	7447
3	7451	7456	7460	7465	7470	7474	7479	7483	7488	7493
4	7497	7502	7506	7511	7516	7520	7525	7529	7534	7539
5	7543	7548	7552	7557	7562	7566	7571	7575	7580	7585
6	7589	7594	7598	7603	7607	7612	7617	7621	7626	7630
7	7635	7640	7644	7649	7653	7658	7663	7667	7672	7676
8	7681	7685	7690	7695	7699	7704	7708	7713	7717	7722
9	7727	7731	7736	7740	7745	7749	7754	7759	7763	7768
950	97772	97777	97782	97786	97791	97795	97800	97804	97809	97813

N	0	1	2	3	4	5	6	7	8	9
950	97772	97777	97782	97786	97791	97795	97800	97804	97809	97813
1	7818	7823	7827	7832	7836	7841	7845	7850	7855	7859
2	7864	7868	7873	7877	7882	7886	7891	7896	7900	7905
3	7909	7914	7918	7923	7928	7932	7937	7941	7946	7950
4	7955	7959	7964	7968	7973	7978	7982	7987	7991	7996
5	8000	8005	8009	8014	8019	8023	8028	8032	8037	8041
6	8046	8050	8055	8059	8064	8068	8073	8078	8082	8087
7	8091	8096	8100	8105	8109	8114	8118	8123	8127	8132
8	8137	8141	8146	8150	8155	8159	8164	8168	8173	8177
9	8182	8186	8191	8195	8200	8204	8209	8214	8218	8223
960	98227	98232	98236	98241	98245	98250	98254	98259	98263	98268
1	8272	8277	8281	8286	8290	8295	8299	8304	8308	8313
2	8318	8322	8327	8331	8336	8340	8345	8349	8354	8358
3	8363	8367	8372	8376	8381	8385	8390	8394	8399	8403
4	8408	8412	8417	8421	8426	8430	8435	8439	8444	8448
5	8453	8457	8462	8466	8471	8475	8480	8484	8489	8493
6	8498	8502	8507	8511	8516	8520	8525	8529	8534	8538
7	8543	8547	8552	8556	8561	8565	8570	8574	8579	8583
8	8588	8592	8597	8601	8605	8610	8614	8619	8623	8628
9	8632	8637	8641	8646	8650	8655	8659	8664	8668	8673
970	98677	98682	98686	98691	98695	98700	98704	98709	98713	98717
1	8722	8726	8731	8735	8740	8744	8749	8753	8758	8762
2	8767	8771	8776	8780	8784	8789	8793	8798	8802	8807
3	8811	8816	8820	8825	8829	8834	8838	8843	8847	8851
4	8856	8860	8865	8869	8874	8878	8883	8887	8892	8896
5	8900	8905	8909	8914	8918	8923	8927	8932	8936	8941
6	8945	8949	8954	8958	8963	8967	8972	8976	8981	8985
7	8989	8994	8998	9003	9007	9012	9016	9021	9025	9029
8	9034	9038	9043	9047	9052	9056	9061	9065	9069	9074
9	9078	9083	9087	9092	9096	9100	9105	9109	9114	9118
980	99123	99127	99131	99136	99140	99145	99149	99154	99158	99162
1	9167	9171	9176	9180	9185	9189	9193	9198	9202	9207
2	9211	9216	9220	9224	9229	9233	9238	9242	9247	9251
3	9255	9260	9264	9269	9273	9277	9282	9286	9291	9295
4	9300	9304	9308	9313	9317	9322	9326	9330	9335	9339
5	9344	9348	9352	9357	9361	9366	9370	9374	9379	9383
6	9388	9392	9396	9401	9405	9410	9414	9419	9423	9427
7	9432	9436	9441	9445	9449	9454	9458	9463	9467	9471
8	9476	9480	9484	9489	9493	9498	9502	9506	9511	9515
9	9520	9524	9528	9533	9537	9542	9546	9550	9555	9559
990	99564	99568	99572	99577	99581	99585	99590	99594	99599	99603
1	9607	9612	9616	9621	9625	9629	9634	9638	9642	9647
2	9651	9656	9660	9664	9669	9673	9677	9682	9686	9691
3	9695	9699	9704	9708	9712	9717	9721	9726	9730	9734
4	9739	9743	9747	9752	9756	9760	9765	9769	9774	9778
5	9782	9787	9791	9795	9800	9804	9808	9813	9817	9822
6	9826	9830	9835	9839	9843	9848	9852	9856	9861	9865
7	9870	9874	9878	9883	9887	9891	9896	9900	9904	9909
8	9913	9917	9922	9926	9930	9935	9939	9944	9948	9952
9	9957	9961	9965	9970	9974	9978	9983	9987	9991	9996
1000	00000	00004	00009	00013	00017	00022	00026	00030	00035	00039

INDEX